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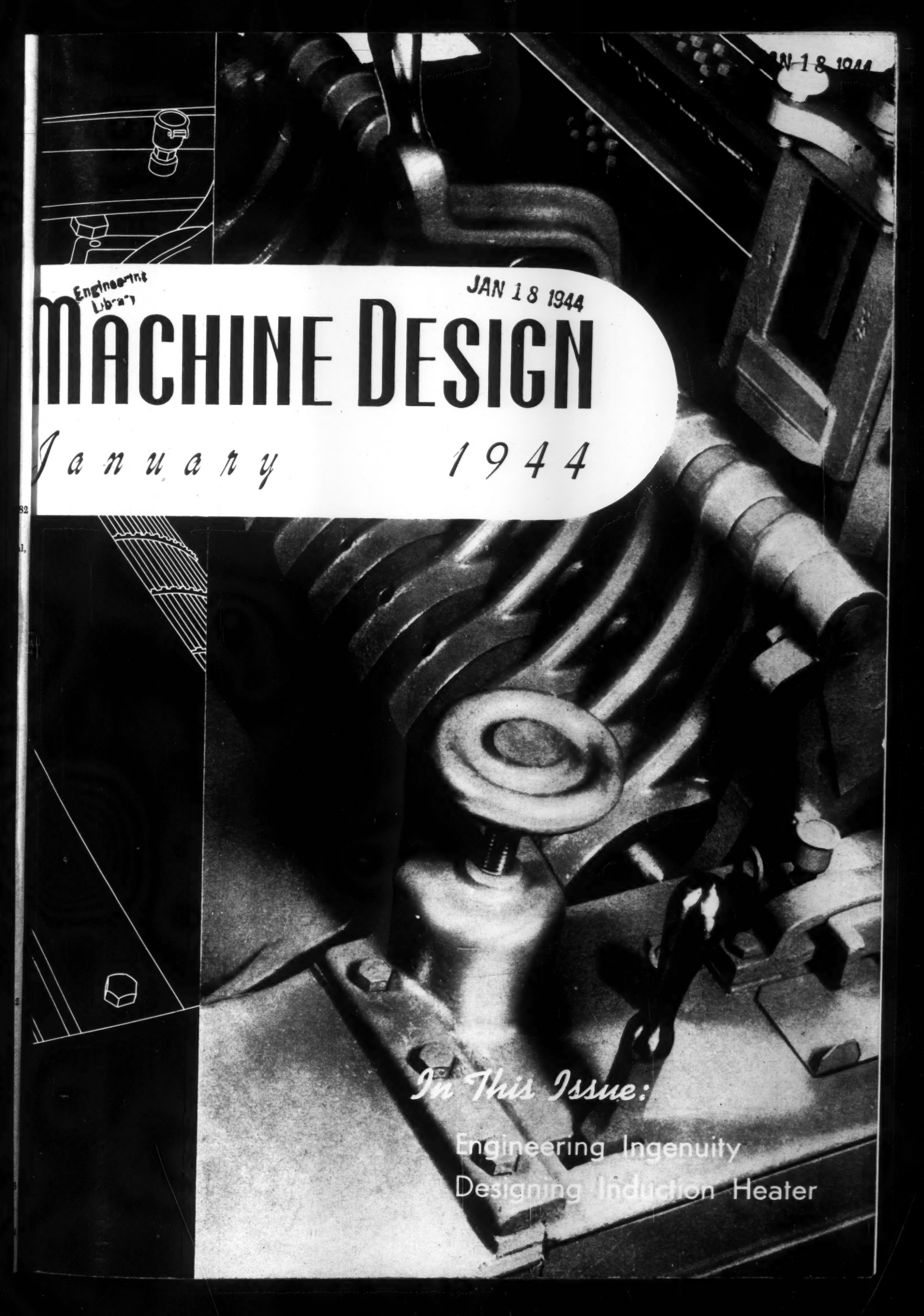
MACHINE DESIGN

January 1944



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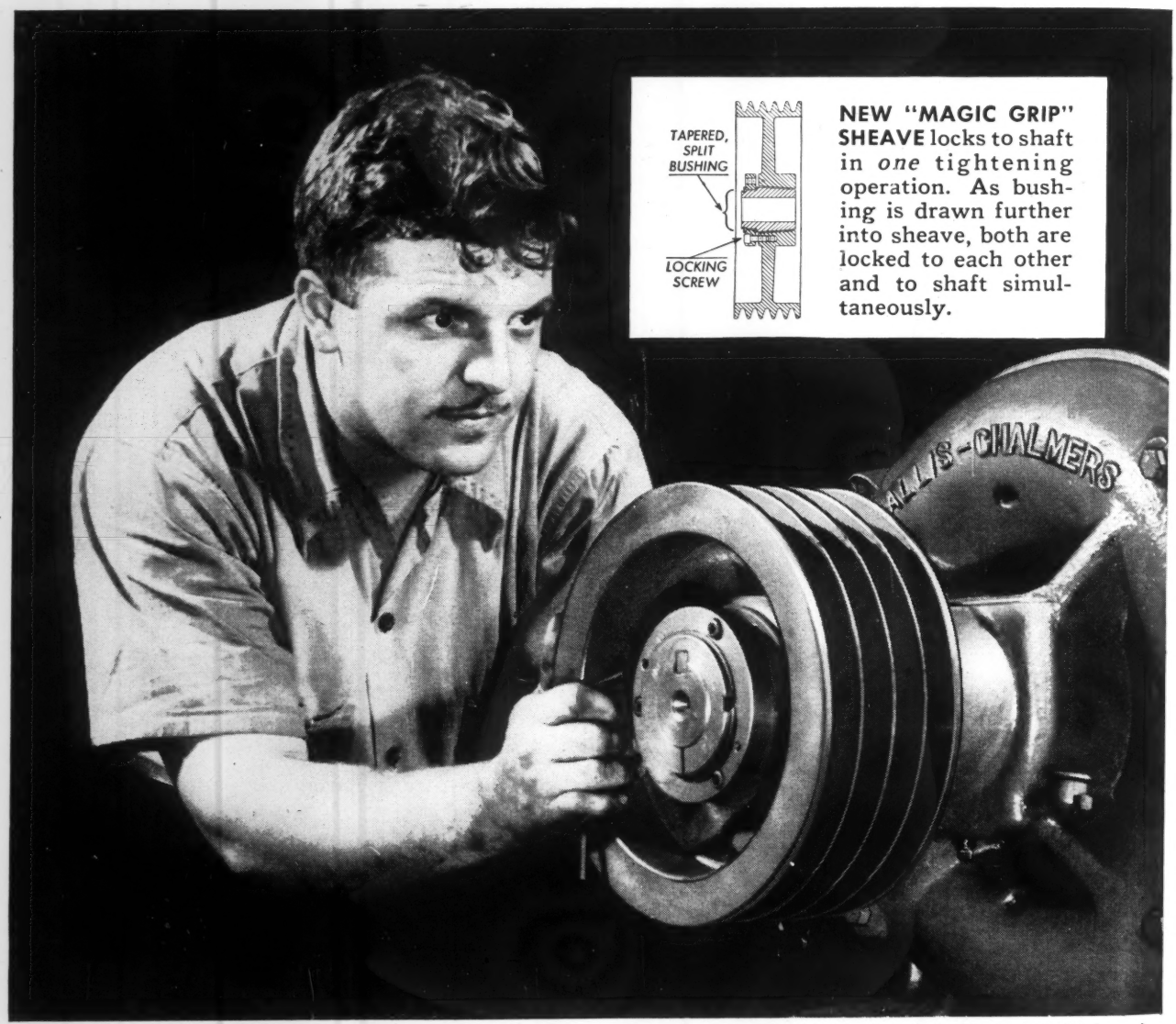
Designing Induction Heater

PRODUCT OF THE MONTH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MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

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On fighting craft of every kind, on land and sea and in the air, New Departure ball bearings prove their superiority . . . every day, every hour, every minute.

It is New Departure's privilege to play the lead in wartime production of ball bearings, enlarging an experience already enormous. Out of this *total* experience will come postwar performance of New Departure Ball Bearings that will set even higher standards of service life. 3220

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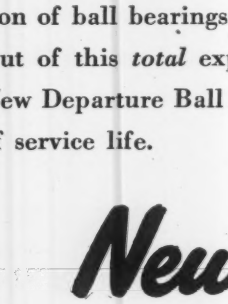

Nothing Rolls Like a Ball

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONNECTICUT

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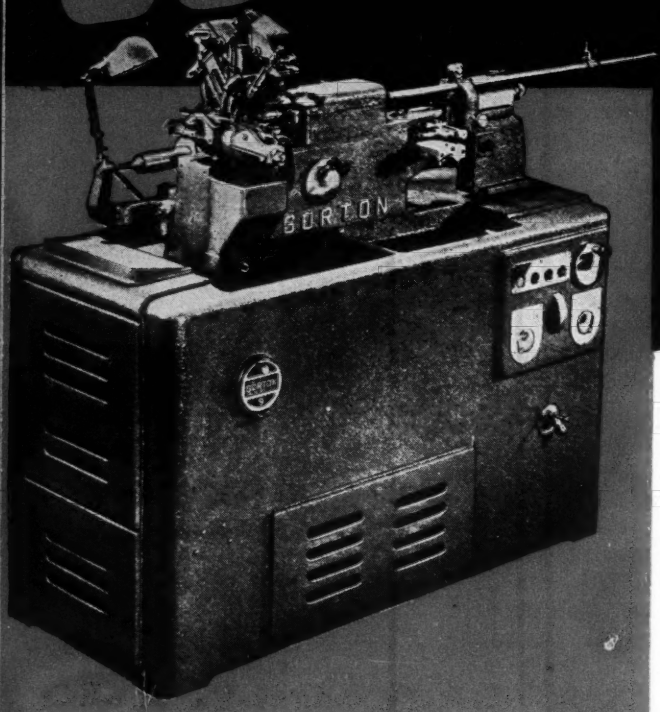
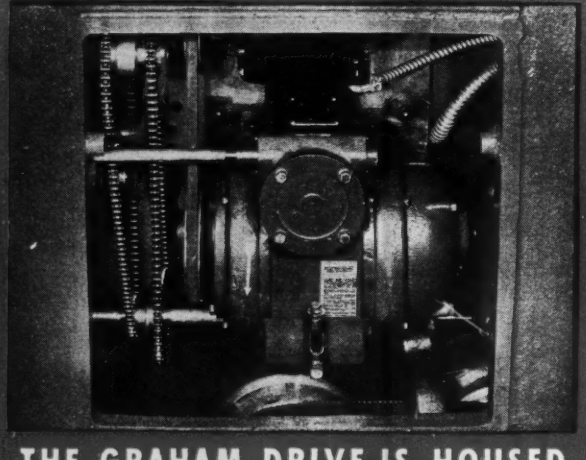
For SCREW MACHIN FEEDS as in th NEW GORTO 16-A AUTOMAT



INFINITELY VARIABLE CAM FEEDS are an important advantage of the new Gorton 16-A, which meets the critical need for an automatic screw machine that will produce small close-tolerance parts in large quantities:—It produces long, slender pieces in multiple diameters —threaded, tapered and knurled. It back recesses, centers, drills and taps. A turn of the knurled wheel shown in the control panel gives complete choice of feeds — from top to zero.



THE GRAHAM DRIVE IS HOUSED entirely within the streamlined alloy iron base. The photo shows a close-up view of the Graham with the cover removed.

THE *Graham* VARIABLE SPEED DRIVE

has these* **IMPORTANT ADVANTAGES**

*1. UNLIMITED SPEED RANGE

in infinite steps from maximum to zero. The Graham gives a working range to the Gorton of 72 to 1, —from 20 to 1440 pieces per hour.

*2. HIGH SPEED HOLDING

— a vital necessity for the highly precise automatic manufacture of small parts — accomplished in the new Gorton.

*3. ALL METAL CONSTRUCTION

Compactness — simplified lubrication.

These same features have led to the adoption of the Graham for a great variety of other machines requiring a superior wide-range drive at moderate cost.

Write for Bulletin number 506

GRAHAM TRANSMISSIONS, INC., 2706 N. Teutonia Ave., Milwaukee, Wisconsin

MACHIN

This issue at a glance

"An Inventor Can Fail A Thousand Times . . . .

. . . but if he succeeds once, he is 'in'."—So said "Boss" Kettering in his inspirational talk delivered at the recent A.S.M.E. annual meeting in New York. In the development of new inventions, just where does "book larnin'" leave off and inherent ingenuity begin? Should inventors consult reference books before or after conceiving the approach to a problem? This talk is down-to-earth—emphasizes a working procedure for development of new ideas based on Dr. Kettering's many years of experience in the research field. Page 111.

Heart Of Ingenious Radar Equipment . . . .

. . . electronic tubes are playing a vital role in Uncle Sam's big show—winning the war. Intricate gun-firing controls owe their amazing accuracy in many cases to these almost infinitely fast and inertialess tubes. When incorporated in properly designed circuits, they can supplement mechanical control to achieve results hitherto considered impracticable. W. D. Cockrell's authoritative article discusses the operating principles of such tubes, functioning of circuits and practical electronic applications. Page 140.

Redesigning For Built-Up Brazed Construction . . . .

. . . often is responsible for considerable savings in the fabrication of mass-produced machine parts. A case in point—production of small overrunning clutch parts at the rate of 8,000 per day—saw a saving of five cents per item by the simple expedient of redesigning from one-piece solid to two-piece brazed construction. In his interesting article "How to Utilize Brazing in Design", Colin Carmichael evaluates the variety of heating processes generally employed and discusses significant factors which influence the design of brazed assemblies. Page 120.

Designing For Straight-Line Production . . . .

. . . was, in prewar days, largely confined to the automotive field. More recently, however—lashed by the unrelenting demands of an all-out war program—other industries have adopted this speedy manufacturing method. But, topping even the straight-line principle is a new machine—utilizing a rectangular path—the design of which is discussed in an article commencing on Page 116.

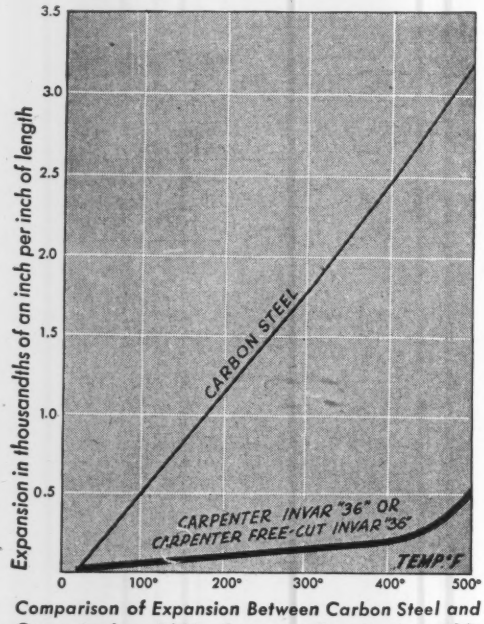
Increased 70 Times Since 1939 . . . .

. . . and 35 times since Pearl Harbor, today's output of magnesium in this country totals 300,000 tons per year. Fifteen plants are now in production supplying this lightest of metals to the arsenals of democracy. Thus, this month's Materials Work Sheet takes on particular significance. Presenting—in brief form—all of the materials data machine designers normally require on the job, this sheet deals with wrought forms of magnesium covered by A.S.T.M. specifications. Page 153.

Where Could You Use These Low Thermal Expansion Properties?

CARPENTER INVAR "36" has an expansion rate of about one-tenth that of carbon steel, up to about 400° F. This 36% nickel alloy, melted within a carefully determined range, has two principal uses:

1 *Maintaining accuracy* by minimizing changes in size of parts due to temperature variation — such as in switch contacts, condenser parts, instrument parts, etc.



Comparison of Expansion Between Carbon Steel and Carpenter Invar "36" or Carpenter Free-Cut Invar "36"

Average Coefficients of Expansion of Carpenter Invar "36"	
75° to 200° F.	.0000006
75° to 300° F.	.0000009
75° to 400° F.	.0000015

2 *Causing movement in temperature control applications,* such as thermostats, where a low expansion alloy is used in conjunction with a high expansion alloy. A rod and tube assembly may be used, or design may require a yoke of high expansion combined with an internal spring of low expansion; or bimetal may be used.

Carpenter Invar "36" is in every respect a true Invar, with a typical expansion curve like that shown in the accompanying graph. In strip form Carpenter Invar "36" permits easy blanking and forming. Where machining is necessary in the production of Invar parts, the newly-developed *Carpenter Free-Cut Invar "36"* greatly facilitates production.

Take advantage of Carpenter's experience in the production and application of these Invar alloys. Your nearby Carpenter representative can give you a copy of our latest engineering bulletin covering their properties and uses, and will keep you in close touch with our Metallurgical Department. For help with your specific problems, call on him today.

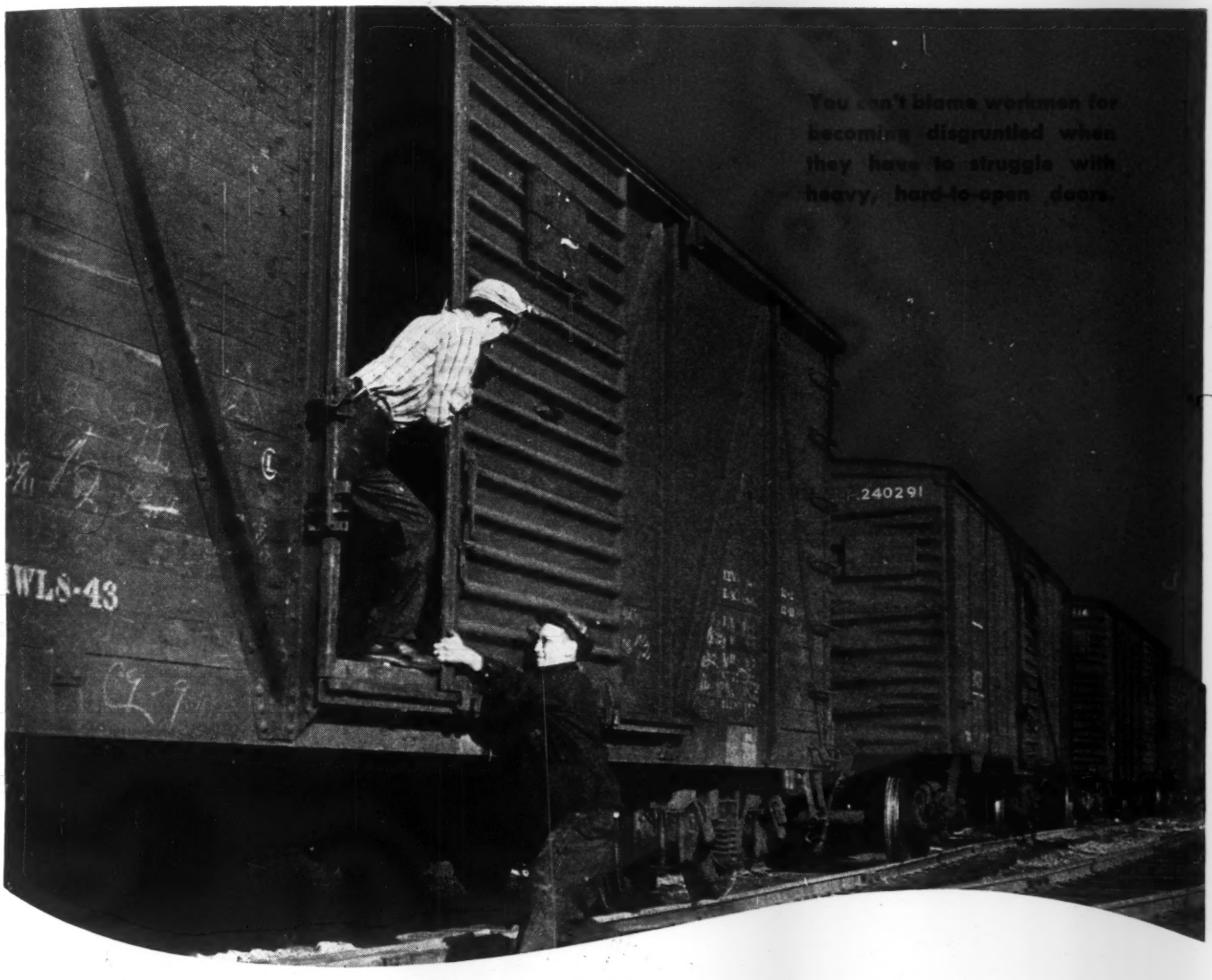
FORMS AVAILABLE

Carpenter Invar "36" and Free-Cut Invar "36" are supplied in the forms of cold drawn wire, hot rolled, cold drawn and ground bars and rods. *Carpenter Invar "36"* is also supplied in the forms of cold rolled strip and welded tubing. Hard rolled strip is made to meet special needs.

The Carpenter Steel Company, 120 W. Bern Street, Reading, Pa.

Carpenter
High Nickel Alloys

- Temperature Compensator "30"
- Carpenter Invar "36"
- Carpenter Free-Cut Invar "36"
- Glass Sealing "42"
- High Permeability "49"



Aluminum will make that a one-man door

No need to make boxcar doors heavy to make them strong. Aluminum will provide the lightness necessary for easy opening and closing, the rigidity and strength required for protection and permanence. Look at the many places in wartime airplanes where Alcoa Aluminum Alloys are doing exactly that kind of job.

In these days of shortages of many materials, it's quite possible that Aluminum can be obtained for doors for the new boxcars scheduled to be built. No extra man-hours will be needed to fabricate aluminum doors, and think of the man power and dispositions saved when these cars get into service.

Imagineers who are seeking ways of improving rolling stock to be built for wartime service, and for postwar use, may well examine the advantages gained by employing Alcoa Aluminum Alloys. Weight-saving usually means labor-saving. And, because aluminum is highly resistant to corrosive attack, equipment is less likely to be injured by unavoidable neglect.

Alcoa engineers offer their assistance to men who are doing this kind of thinking. ALUMINUM COMPANY OF AMERICA, 1940 Gulf Building, Pittsburgh, Pennsylvania.

ALCOA ALCOA ALUMINUM REG. U. S. PAT. OFF. **ALUMINUM**

ELIMINATION of the plating operation and substitution of one coat of cement for the two formerly used for ignition wire sleeves on aircraft engines saves a relatively large quantity of brass as well as considerable production time. The sleeves are essential for the elimination of corona or dissipation of the electrical charge before it reaches the spark plugs.

Midget microphone, worn on the upper lip, eliminates outside noises and leaves hands free. Adopted by the Army Ground Forces, the lip mike fits easily under gas masks and dust respirators, giving clear reproduction with little distortion.

On a test flight the Martin Mars, the world's largest flying boat, flew 4600 miles—equivalent to a nonstop trip from Baltimore to Berlin and back to London—and still had enough gas left in the tank for several more hours flying. The flight bettered the international closed circuit distance record by approximately 50 per cent.

High chemical resistance and other properties make Saran especially fitted for use as a mask to prevent chrome from plating certain parts of aircraft landing gear during the plating processes.

Standards which were good enough for testing natural rubber are not good enough for synthetics. To provide for such uniformity that products may be used interchangeably, the National Bureau of Standards is cooperating with the Rubber Reserve Co. in its efforts to develop uniformly high quality from the eleven synthetic plants.

Heavy, long-range bombers will be powered with Wright cyclone engines of 2,200 horsepower, among the most powerful service aircraft engines in the world. The engine, built in two banks of nine cylinders, has a displacement of 3350 cubic inches and a diameter of only 55 inches. Engine weight is slightly over one pound per horsepower, special design features allowing for increased output. Nose section permits close-fitting cowl, cylinder heads are alloy aluminum, cylinder barrels use nitralloy steel, crankcase is steel and nose section and supercharger are magnesium.

Photomicrographs of sintered powder metal parts at magnifications ranging up to 20,000 diameters reveal that particle boundaries under proper sintering conditions are completely obliterated, producing a continous metallic structure. Investigation is being carried on by Hardy Metallurgical Co. in cooperation with RCA laboratories.

Lighting by wireless transmission, although probably many years in the future, will open new possibilities in design. Remote or critically limited locations where conventional connections of electrical wires would create restrictions, could be adequately and conveniently lighted. On an experimental scale, lighting can be provided through high-frequency radio energy, envisioning the possibilities of future developments.

Obviating laborious hand wrapping and grease coating of ordnance parts to protect against corrosion, the Dow Chemical Co. has developed a skin-tight coating that is applied by dipping. The plastic "skin" is easily removed by stripping with a knife, leaving a clean surface with no grease or foreign substance on the part.

Doubling of life of one-inch steel slugs or balls used by cement makers as grinding media is said to be obtained by induction hardening. An estimated saving of 7500 tons of steel a year is possible.

Production of electrical indicating and measuring instruments used in mechanized warfare has soared 4000 per cent since 1940. WPB estimates call for a further increase of 40 per cent in 1944, totalling 39,000,000 units. Indicative of the importance of instruments in war a battleship uses as many as 1000, a large bomber 250 and a submarine 150.

New celestial navigation instrument—combining a sextant for use during the day and a quick means of determining true north, sun time, latitude, great circle course and direction—has recently been designed especially for use in life rafts. Invented by F. H. Hagner of San Antonio, the instrument reproduces the movements of all the celestial bodies used in navigation.

MACHINE DESIGN

KETTERING High-Spots the Training of Inventors

I THINK it was the Brookings institution that made a survey some years ago and pointed out the fact that if you had an education in engineering or science your chances of making an invention would only be half as great as if you did not have it. Well, that worried me a bit and I tried to find out why it was, and I think out of it I got a definition of what an inventor is: An inventor is a guy who doesn't take his education too seriously.

As our educational institutions are set up a youngster, from the time he is six years old until he graduates from school, has to take three or four examinations a year. If he flunks once, he is out, whereas an inventor can fail a thousand times and if he succeeds once, he is in. So the two methods of approach are entirely different.

The thing to do is to teach the educated boy how to fail intelligently, because if we don't he will come in some day with a book in his hand and say, "There is no use to try this out because here it says on page 284 that it can't be done."

"Well," we say, "what did you read the book for? That is no way to solve a problem—reading a book—because any time that you don't want to do a thing I can get you a book that will tell you that it can't be done."

Seriously, in training an inventor, how close do you want him to work with the library? Of course, there is a good argument as to whether you ought to go and see what has been done on the subject before going ahead, or whether you should start out and pursue your own thoughts and then find out what has been done.

I believe that what you should do is set up your

From a talk delivered at the recent annual meeting of the American Society of Mechanical Engineers in New York.

problem. Think it out. Say, "Here is the way I think it ought to be done", and *then* go and see what has been done on it. So the first thing is to analyze the problem and decide whether the thing is worth doing. Then if it is worth doing, what is probably the first experiment that should be tried?

Well, let's try this one. Don't worry about what is going to happen, because if you did know you wouldn't need to try the experiment. So you make the experiment and then come to a certain conclusion based on it. If you doubt it too much, you try it over again. In fact, you ought to try it over ten times, because the first time it is probably no good.

If it doesn't work, you have to find out whether it is because the experiment was wrong or because it was not done well. So you have to try it over and countercheck and check again. After you have failed or after a continuity has been established, then you analyze it and try the next step. You decide on what the second experiment is going to be and you go through with that, always recognizing the importance of the technique of trying the experiment.

And a lot of people do not want to do that. It is pretty tedious work. The only reason, I think, that our laboratory has ever done anything is that none of us knows enough to get irked by the tediousness of experimentation.

Therefore, the next thing that we teach these young fellows is that tediousness is a thing that they must learn to endure and like, and not resent because they have an education.

Getting an Idea Through the Human Skull

Now, you don't solve these problems and you don't make these inventions in a laboratory. You make them in your head. That is where every bit of this work is done. How thick and how dense the skulls of human beings are is best represented by the amount of technological apparatus we have to have in a place like ours for just getting an idea through a quarter-inch of skull bone. That is all that apparatus is for—not to solve the problem but to change a mental attitude, and that is a very difficult thing to do.

I am a great believer in experimentation because of the fact that in our class of work, we have never been able to calculate anything. We can calculate a very rough first approximation. If you have a factor of safety of ten, you can do a good job of calculation, because a factor of safety of ten says that you aren't betting your calculations are more than ten per cent right; so the bigger the factor of safety, the more leeway you can have in your calculations.

It was for this reason that some ten or fifteen years ago we started a new system of studying strength of materials which had to do only with testing the final piece under the conditions in which it had to operate. In other words, if we are developing a crankshaft for an engine, we make the crankshaft and build a testing machine that will stress that crankshaft as it is in the engine, because if we put it in the engine and it breaks, the debris is such that we can't be sure of what happened.

Then, after we set this up in a testing machine, we put on anticipators, or some device that stops the machine the minute an incipient crack starts in the shaft. Then we can find out where it started and why.

By this means we have been able to raise the fatigue life of parts as much as five hundred per cent, by doing nothing more than change the fillets and make slight shifts of temperatures in heat treatment.

Another thing that we have to do with boys whom we try to train as inventors is to teach them that being a good technologist does not necessarily make a man a good diplomat. Most engineers are poor on diplomacy, and think that if they can write a report and use a lot of log curves and words which the management doesn't understand, that establishes their position.

It is important also to get your inventor not only to understand the technical problem but to recognize that because he knows a few formulas about it, or has seen some circuit or some mechanism of this kind, he doesn't necessarily understand it.

We don't, for instance, know the first principles of what happens when you slide two things on each other. I would like to know. I think maybe the problems that I am interested in are low-grade problems that are too low for high-grade people to work at, but that is where we have to work, anyway. Therefore, we try to teach young fellows that it is no disgrace even to work on a thing like trying to find out what friction is.

Which of Us Is Crazy?

Whenever you look at a piece of work and you think the fellow was crazy, look out, because he either is or he isn't. But one of you is likely to be, and you had better find out which one it is. It makes an awful lot of difference.

Which brings up the question of training the fellow not to have too much of an opinion or set too much value on his own opinion, because his opinion and the things that he does are not evaluated by himself at all. These things are facts or are not facts—regardless entirely of what people think they are—according to whether they conform to certain factors in engineering. And so, it is hard to get people to look at a thing and take off the personal concept that: "It must be good or I wouldn't have thought of it."

Well, if you could get out of the young man's mind the idea that because he thought of a thing has very little to do with it and that regardless of what the thing is, it is an entity independent of what he thinks, then you can go ahead without the danger of temperament getting into engineering.

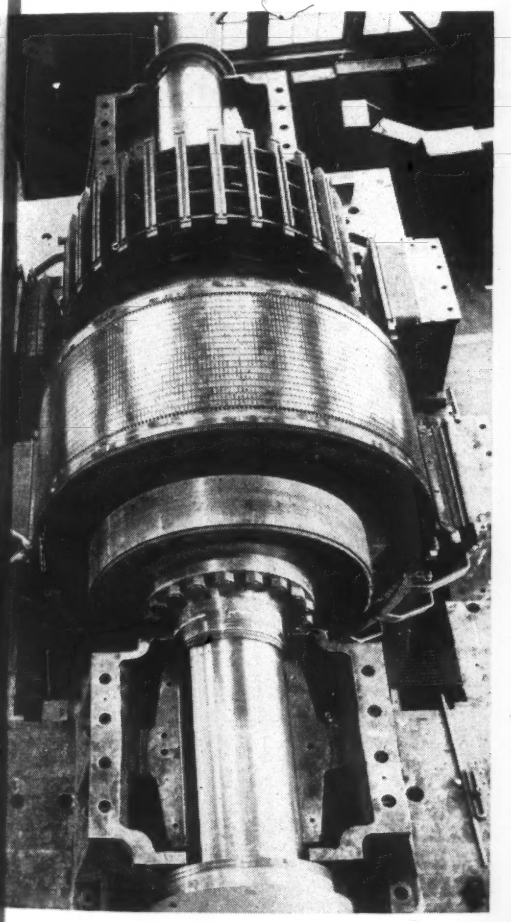
Question Everything!

We try to teach our boys in the laboratory and every other place that the questioning of things is very important. We have done a lot of questioning on various things, and we get certain rules and regulations which we write down and accept as being fundamental dicta. We tried one two or three years ago that was very, very interesting.

We took a flat piece of spring steel, about three inches wide and two feet long, and laid a flexing machine on it whereby we could bend it. We found that the standard

(*Concluded on Page* 200)

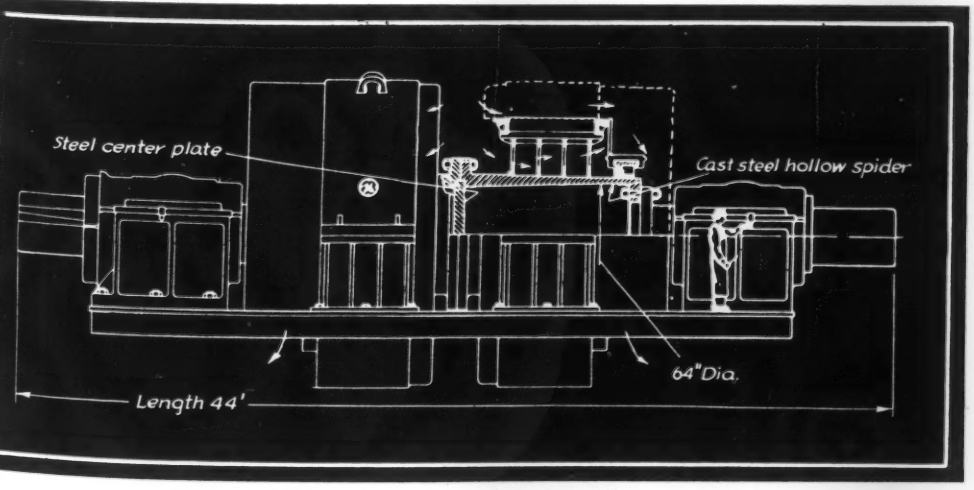
Scanning the field for IDEAS



STUB-SHAFT construction for double-armature motor shown at left obviates the conventional through shaft. For this particular motor a forging so large would be required that it would be difficult, if at all possible, to obtain under present wartime conditions. Unique in design as indicated in the drawing below the two steel armature spiders are bolted together with the stub shafts bolted to each hollow spider to support the whole assembly in two bearings.

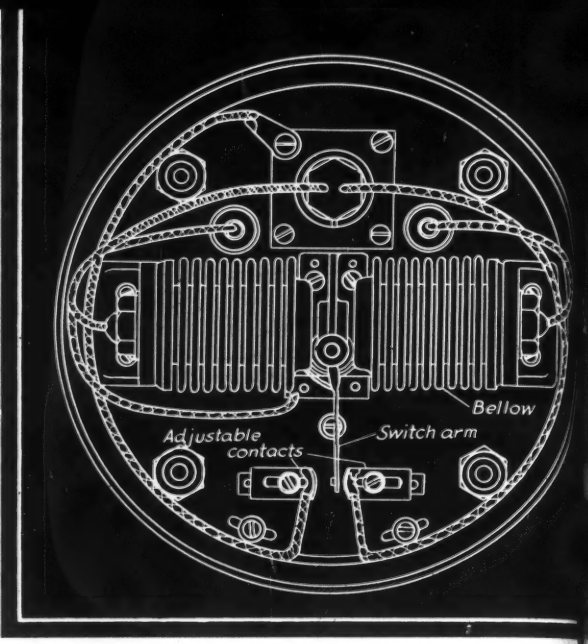
Having a rating of 7000 horsepower, this General Electric motor develops the largest torque ever provided in a motor—4,100,000 foot-pounds momentarily or 1,470,000 continuously. It weighs approximately 1,000,000 pounds and has an overall length of 44 feet. The two bearings have journals 34½ inches in diameter. Such large journals and low speeds of 25 revolutions per minute make oil ring lubrication impractical. Hence, flooded lubrication is used. Armature spiders are cast steel having an inside diameter of 64 inches. The flanges are kept in line by a circular steel centering plate. Torque is transmitted partly through steel radial keys and partly through the clamping effect of the bolts.

If built with a conventional through shaft, the shaft diameter would be approximately 60 inches to give proper stiffness. Instead the construction shown approximates the stiffness of a 72-inch solid forged shaft. Another advantage of this type of construction involves simplified erection. It is easier to bolt together the two armatures and the two short stub shafts than to press two armatures on a single shaft.

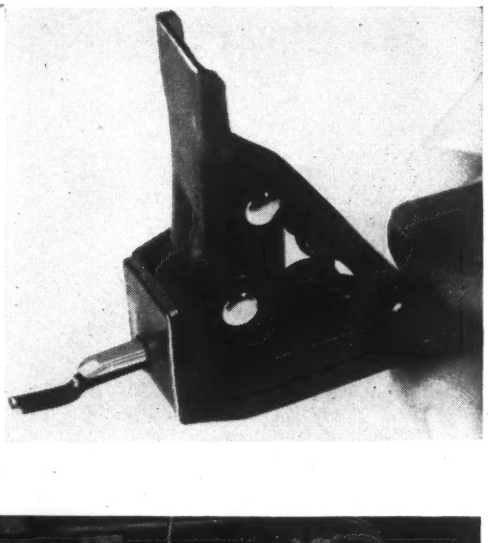


Opposed metallic bellows, connected through a linkage to switch arm provide an air-pressure sensitive switch for automatic control of

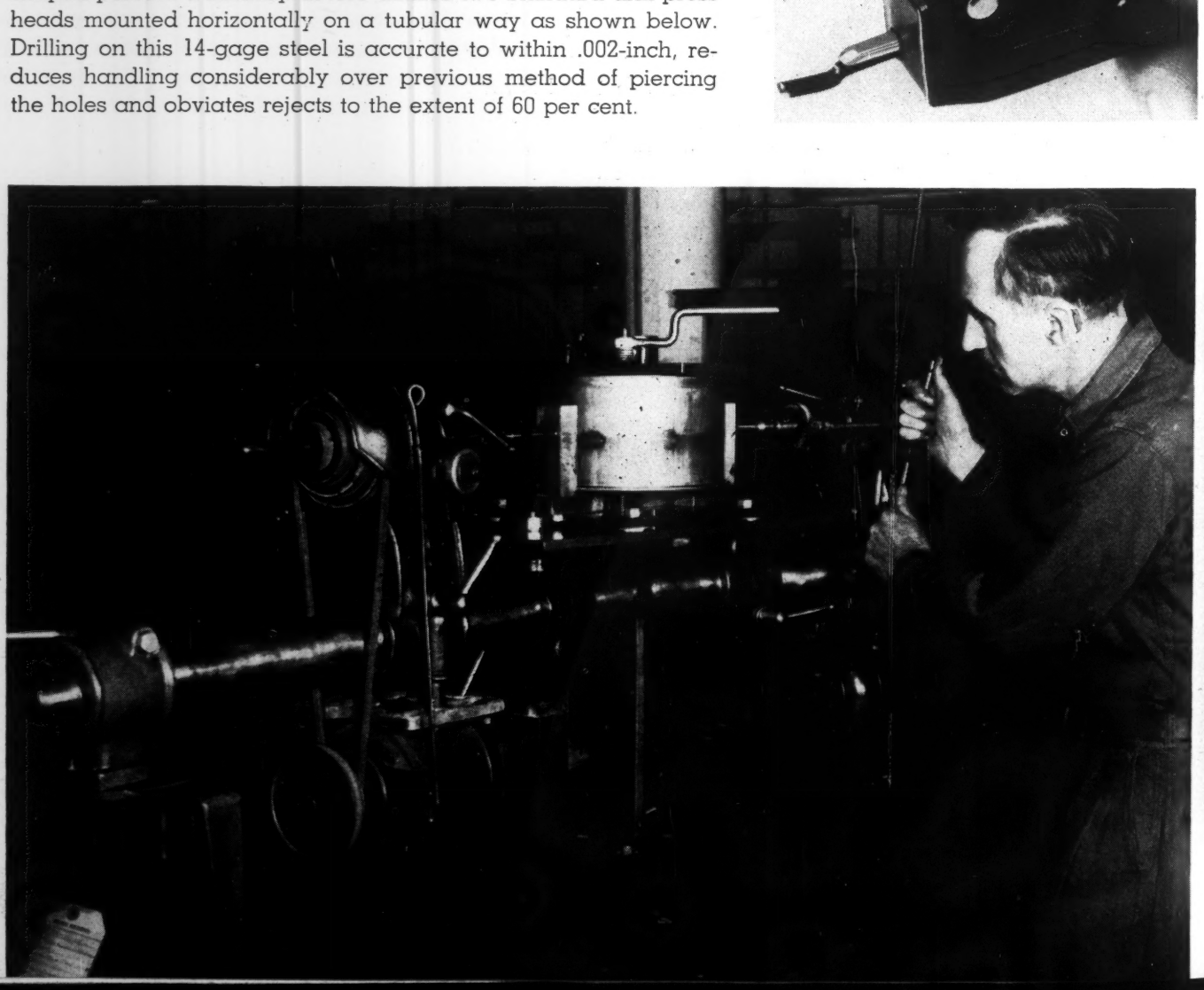
an aircraft's flap system. Designed by Kenyon Instrument Co., the volume of air required to operate the switch, shown at right, has been reduced to a minimum by utilizing plugs to fill the center chamber of each bellows. These plugs also form one end of the bellows for mounting purposes and provide an internal limit stop for the opposite end of the bellows in the compressed position. The switch is designed to have snap action and to operate satisfactorily under all conditions of aircraft vibration. Operated through a T-connector in the pilot-static lines between the air-speed switch and the pilot-static head, pressure range is readily regulated by simple adjustment of the contact points between which the switch arm is hung.



Designed for women workers especially, the skin fastener at right is operable with eight pounds pressure exerted on levers held between thumb and forefinger. Aircraft skin assembly for either flush or countersunk rivets is made possible through action of a hot-drawn, oil-tempered torsion spring, effecting a direct pull of 35 pounds at the point of contact with the skin.



Special machine for accurately drilling holes on a pan-shaped part for a military device utilizes two standard drill-press heads mounted horizontally on a tubular way as shown below. Drilling on this 14-gage steel is accurate to within .002-inch, reduces handling considerably over previous method of piercing the holes and obviates rejects to the extent of 60 per cent.

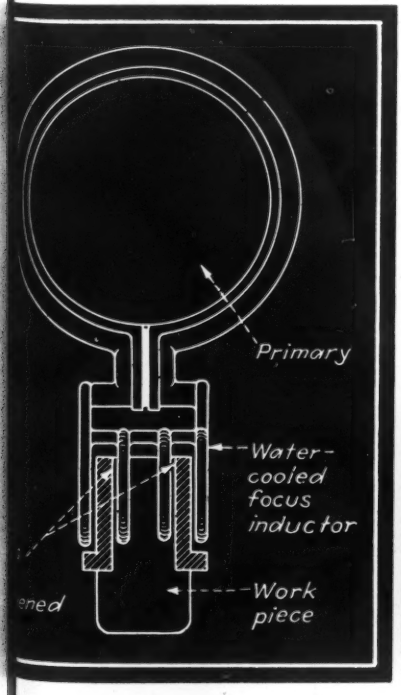


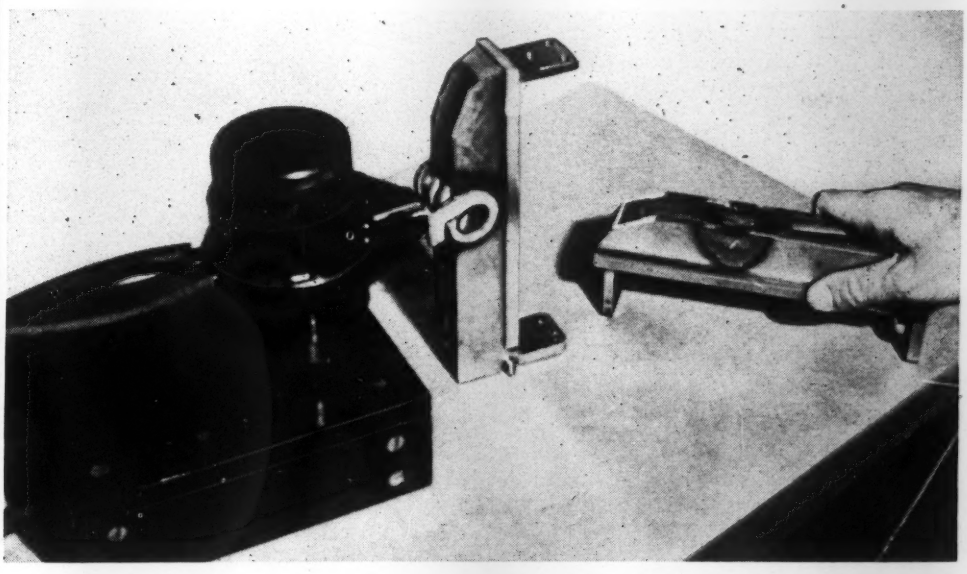
Blasting has proved a practical method of reclaiming partially machined parts in which broken tools have become lodged. Although highly unconventional, the method, developed by the Ohio Crankshaft Co., has been used to advantage on many crankshafts in which drills or taps have broken in oil holes in the shafts.

Skillful use of the high explosive never requires more than a thimblefull of dynamite. Shown at left is a crankshaft in which preparations are being made to blast a broken drill from an oil hole. A small amount of dynamite is fed into the hole and a six-inch fuse in a shoulder-free cap is dropped into the hole atop the charge. Drills are freed by the pressure of the blast which follows the flutes of the broken drill to the bottom of the hole and then reverses itself to drive the piece back out. If the broken drill should be flush with the surface, a putty dam 1½ inches thick is built above the hole. The blast either drives out the drill or enough of it to follow with another charge in the hole. Core drills, 1¼-inch in diameter have also been removed by blasting. For their removal, the dynamite is placed in the oil holes of the drills and blasted out piece by piece.

In the thousands of precision parts subjected to this method of removal there has been no evidence of harm. After blasting, however, each piece is closely inspected and magnafluxed before returning to the line.

Localized heat treatment of an ordnance part is provided by specially designed induction heating coil shown below. Heat is concentrated in area to be hardened by a modified helical coil so that maximum heat is applied to the restricted area. Designed by Ajax Electrothermic Corp., the inductor unit is water cooled and utilizes a 35-second heating cycle at a frequency of 35,000 cycles per second. Power source is a 6-kilowatt spark-gap converter.





Embodying Self-Contained Units In Design

By Richard K. Lotz

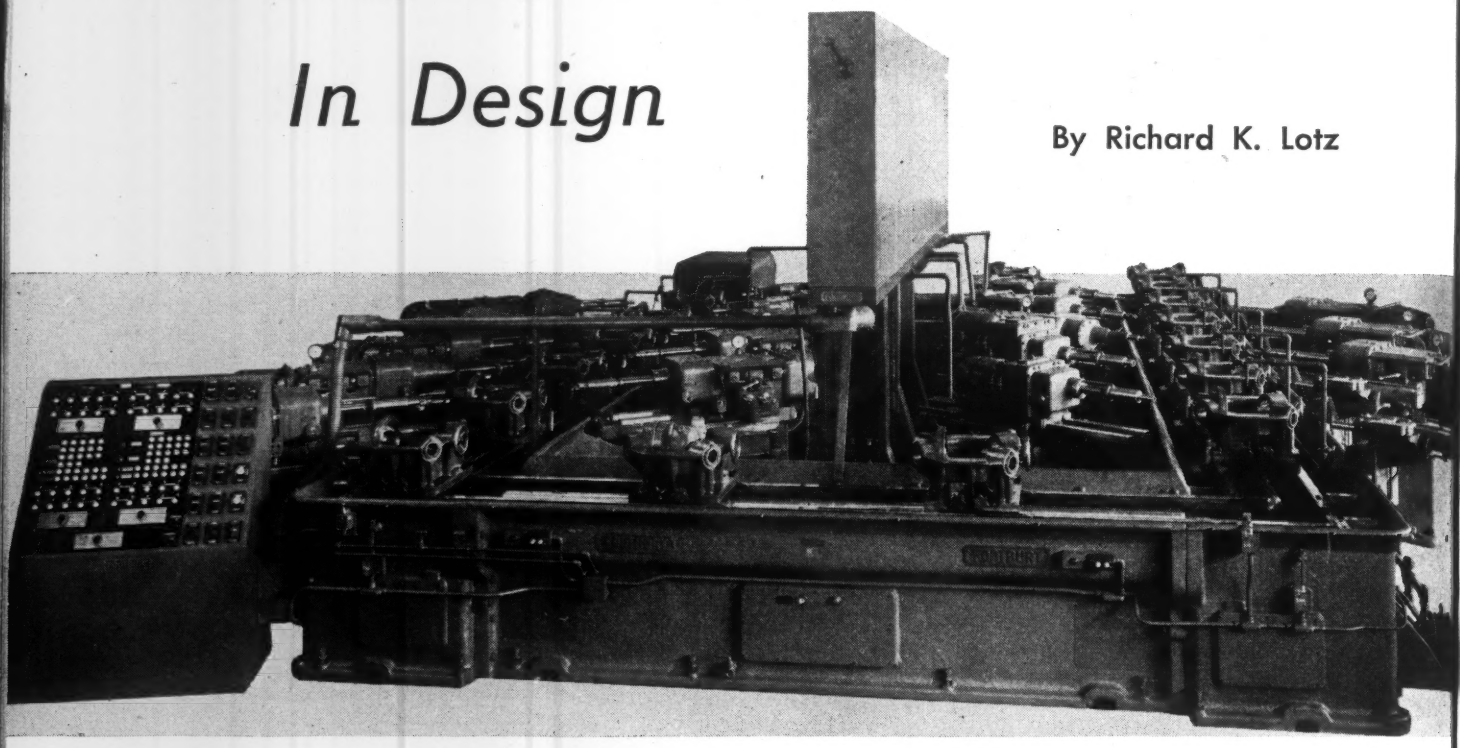
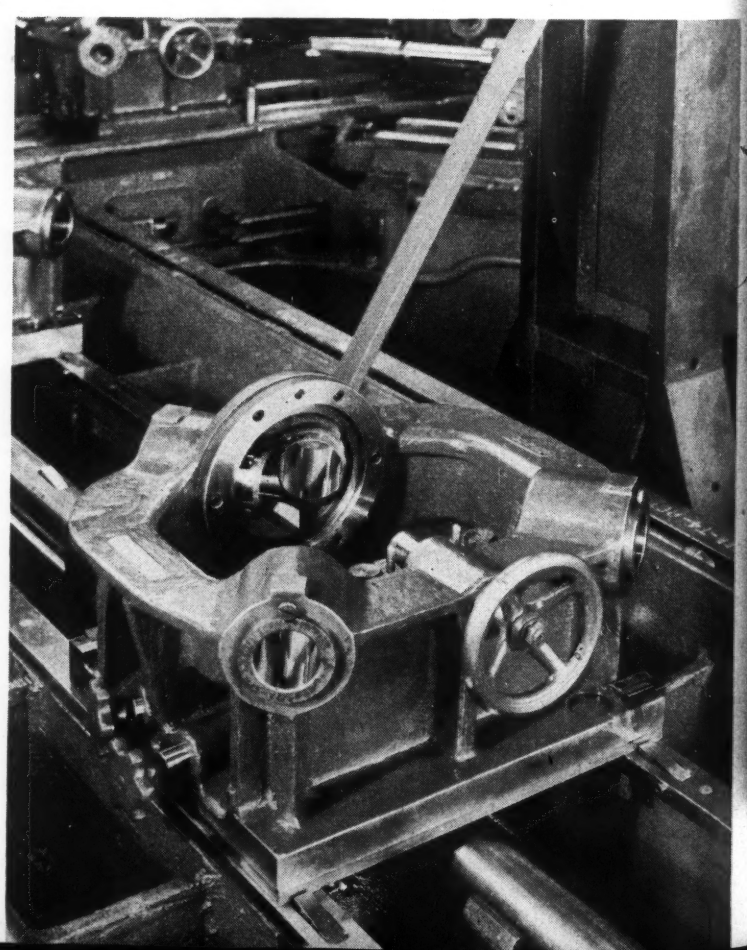


Fig. 1—Above—General view of machine, showing all fixtures in place at the operating stations. "Trouble-shooting" cabinet is located at extreme left

Fig. 2—Below—Fixture in position at one of the stations. Transfer bar is located immediately below fixture



MANY machines utilize, to considerable advantage, integral self-contained units with correlated remote controls. In this article, principles embodied in such equipment are emphasized through discussion of the design features of a specific machine. It is believed that these principles, or an adaptation of them, may well be considered in the development of other kinds of machinery.

Designed and manufactured by The Foote-Burt Company of Cleveland, the machine dealt with in this article automatically performs 16 separate machining operations on aluminum cylinder-head castings for aircraft engines.

Employs Rectangular Path

As will be seen in *Fig.* 1, the machine comprises a bed and ways set in the shape of a rectangle with the parts to be machined clamped in fixtures which are moved intermittently along the ways, stopping at the spindle stations where the various machining operations are performed. Each spindle unit is individually motorized, being interconnected and synchronized electrically. The fixtures are pushed from station to station around the rectangle by means of hydraulically powered and electrically controlled transfer bars.

In analyzing the design of this machine, it is interesting to note the significant manner in

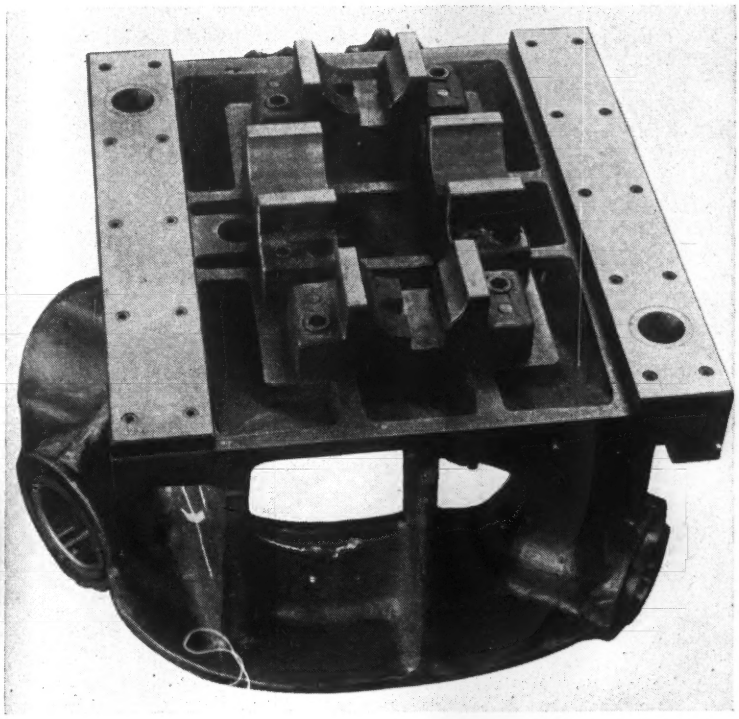


Fig. 3—Above—Bottom view of a fixture, showing slots with which transfer bar pins engage, and two locator-pin bushings

Fig. 4—Below—Schematic diagram of typical interlocking electric circuit with sequence of operations listed at left

which it digresses from conventional procedure. For one thing, it is a departure from other types of multiple-station production machines which have operational stations disposed at intervals along a straight line. It will readily be seen that had such a procedure been employed in this case, the machine would be more than twice as long as it is, would demand more complicated mechanisms, and would not lend itself to the efficient type of centralized control utilized.

Another commendable feature is the manner in which the parts to be machined are handled. They are clamped in a fixture (see *Fig.* 2) and the fixture and part, as a unit, are transferred from station to station. This is in contrast to procedure prevalently employed, in which parts are merely clamped or bolted to a traversing plate or turntable. Each of the fixtures employs four hardened bushings for guiding the cutter spindles at the various operational stations.

The "all-out" manner in which self-contained, remotely controlled units are employed in this machine is noteworthy. Without exception, every mechanical movement for handling the parts is imparted by a separate hydraulic cylinder, the four-way valve of which is actuated by a solenoid.

Basically, the sequence of electrical components for controlling the hydraulic cylinder valves is as follows: At the completion of a

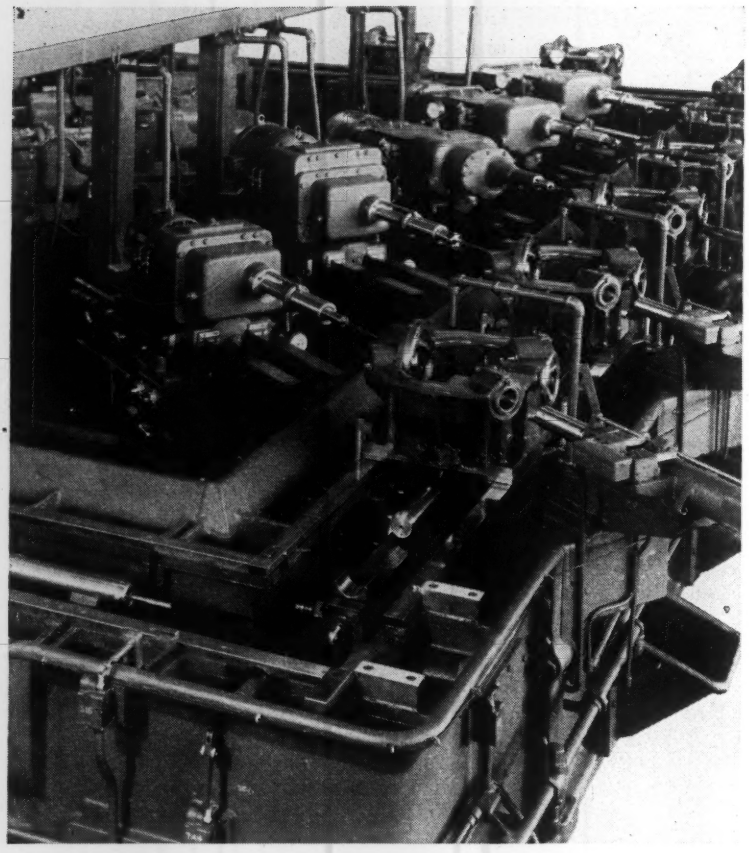


Fig. 5—Above—Fixtures clamped at operating stations along right-hand side of machine

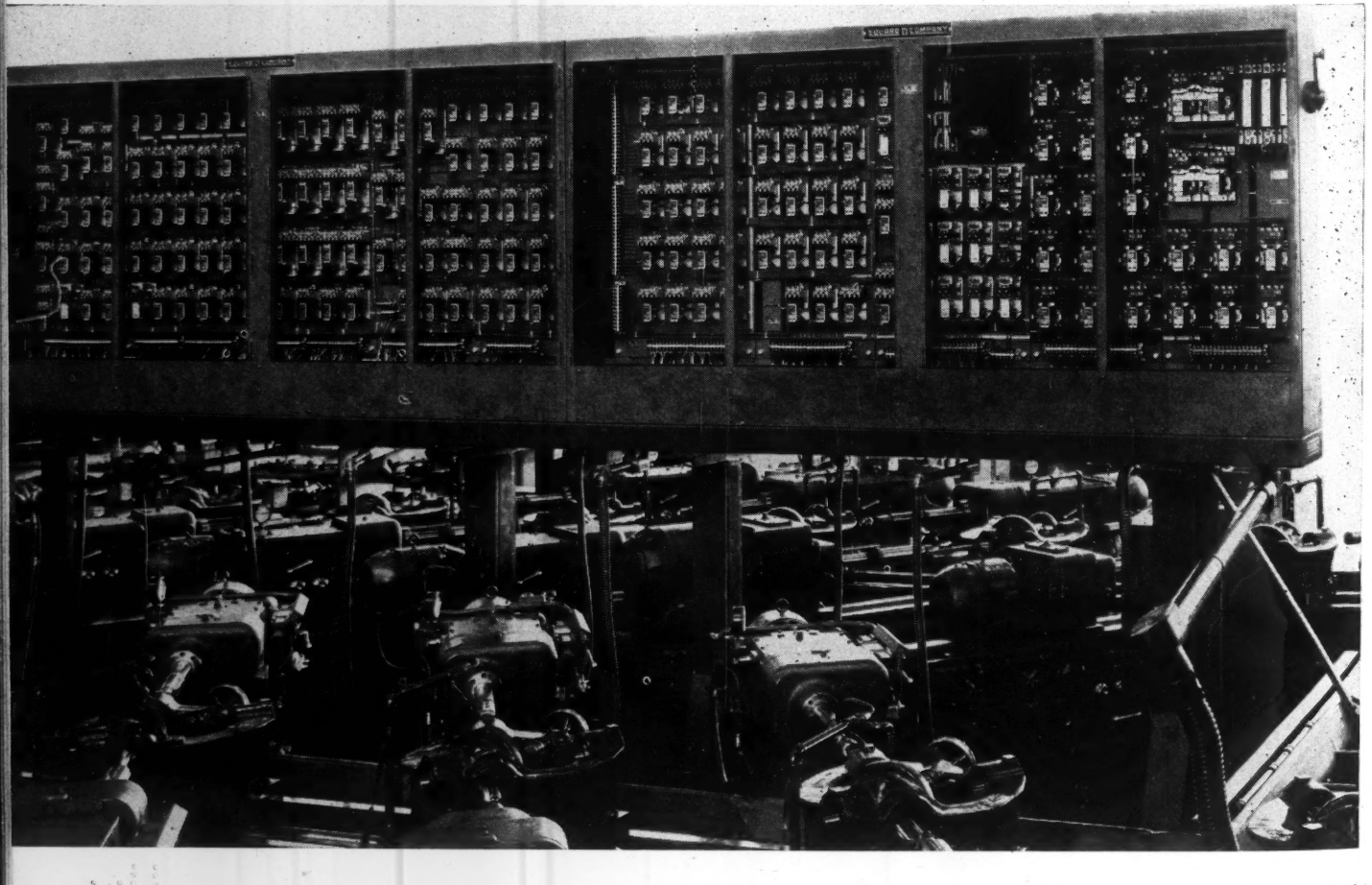
Fig. 6—Below—Main control panel with covers removed showing the large number of relays employed

mechanical movement a limit switch is tripped. This completes the circuit to one or more relays which serve to open or close designated circuits to one or more valve-actuating solenoids. The heart of the electrical portion of this machine, however, is the intricate interlocking system which will be discussed in some detail later.

Since the method for automatically transferring the loaded fixtures from station to station is the same for all four sides of the rectangle, a discussion of the mechanism for any one side will also apply to the other three.

Referring to *Fig.* 1, the foreground end of the machine is employed for loading and unloading the fixtures. Assuming a fixture has been loaded with its cylinder head and is ready to start its circuit of the machine, it is first transferred to the left-hand corner where it is ready to be moved along the left-hand side ways of the machine to the first machining station. A long steel bar (transfer bar), located midway between and slightly below the surface of the hardened steel fixture-guiding ways, moves forward under the fixture and, upon turning axially through 90 degrees, a steel pin projecting from its surface engages a slot in the underside of the fixture base, effectively locking together the fixture and transfer bar. The transfer bar then slides to its extreme position in the other direction, carrying the loaded fixture along with it to the first machining station.

Before the transfer bar can be turned to bring



its pin out of engagement with the fixture slot, it is important that the fixture be accurately located on its ways in reference to the machining-unit spindles. To accomplish this, two steel locating pins emerge vertically from their bearing holes in the ways to engage with hardened steel bushings in the bearing surface portion of the fixture base (see *Fig.* 3). After the locating pins are fully engaged with the bushings of the fixture, the vertical clamp bars are hydraulically brought into action, effectively holding the fixture in position on the ways for the machining operation to be performed at that particular station.

As soon as the fixture has been firmly clamped, the transfer bar turns axially through 90 degrees in such direction as to disengage its pin with the slot in the base of the fixture and moves lengthwise to its neutral position.

All of the mechanical motions referred to are effected by hydraulic power, electrically controlled. For example, the back and forth lengthwise movement of the transfer bar is imparted by a hydraulic piston, the end of which is fastened to the transfer bar through a short steel arm. To turn the transfer bar axially through 90 degrees when it is in position for its pin to engage with the slot in the under side of a fixture, a hydraulic piston again supplies the motivating force. This time, however, since the operational stations of the machine are 50 inches apart, a mechanism is required which will permit the bar to be turned at either end of its lengthwise stroke.

To accomplish this, an arm is rigidly fastened to the transfer bar and the end of the arm is slotted. This slot is a free running fit on a long square bar, each end of which is fixed to the end of a lever. By pivoting these levers, the square bar, working through the slot of the transfer bar arm, transmits rotation from the square bar levers to the transfer bar. The end opposite the square bar on one of the levers is linked to a hydraulic piston. Thus, when the piston moves back and forth, it imparts rotative motion to the square bar levers.

Laying Out Electrical Circuits

In laying out the electrical circuits for this machine, considerable ingenuity was required to insure proper sequence of the many motions and machining operations involved. It would not do, for example, to have the machine attempt transfer of loaded fixtures while machining operations were taking place, or for the transfer bar along the front end of the machine to advance into the left-hand corner while the transfer bar along the left side was also moving into that same corner.

Consequently a system of contacts and relays was developed by means of which the machine either performs in conformance with a prescribed sequence or shuts down until the sequence is once more established. The series of correlated electric circuits employed appear, when viewed in their entirety, to be exceedingly complicated. However, when broken down into individual circuits, the picture presented becomes less complex and, since the same underlying principles are used in all of the unit circuits, an analysis of one circuit will serve to explain the functioning of all. Such circuits, when added together, constitute the entire electrical control equipment.

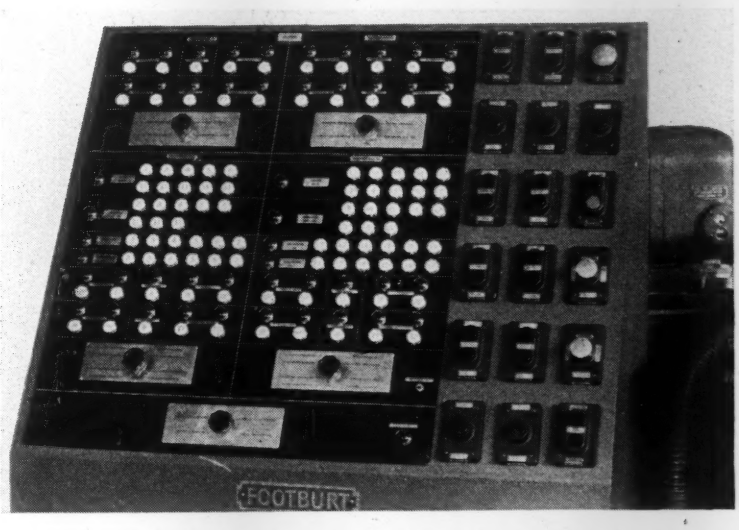


Fig. 7—Panel of "trouble-shooting" pushbutton cabinet showing groups of lights used to spot faulty units in machine immediately

A typical component circuit is that controlling the functioning of the transfer bar which operates along the left-hand side portion of the machine. This circuit is shown schematically in *Fig.* 4. All of the contacts, identified by the letter CR in the diagram, are relay contacts. Those illustrated by double lines with the added cross line drawn at an angle are contacts normally closed, while those without the cross line are normally open. Latch-type contactors are shown as parallel rectangular boxes. Wherever T2 appears on the diagram it indicates the transfer bar. Pushbuttons shown are used for manual operation of the machine and will not enter into the following discussion, which deals with automatic operation only.

Tracing a Typical Circuit

To trace through a typical sequence of operations, a logical place to start is at the instant when the machining heads have been propelled back completely away from the work. Sequence of operations follows the order indicated by the numbers in the circles identified as relays, while the operations themselves are listed at the left.

With the machining heads completely back out of the way, the locating pins must be moved out of engagement with the fixtures. Tracing from the right-hand side of the diagram at "B", the current first passes through a cycle relay (CRC) and thence to the series-connected machining head relay contacts. Since the machining heads are all back, these contacts will be closed, permitting the current to pass along to the normally closed contact (CRTF2). "Fingers up" at this point in the diagram indicates that the pins on the transfer bar are in their engaged position with the fixtures. The current now passes along two branches, one branch (drawn vertical on the diagram) leading through a cycle relay to a relay contact which will be closed only when the transfer bar is in the advanced position. This contact, however, will be open because the transfer bar at this point is in its "returned position". Thus the current will pass through

(*Continued on Page* 202)

How Ti

Part II—Brazing Processes

By Colin Carmichael

Fig. 8—Incandescent carbon brazing employs water-cooled tongs and pushbutton control of current under the operator's thumb

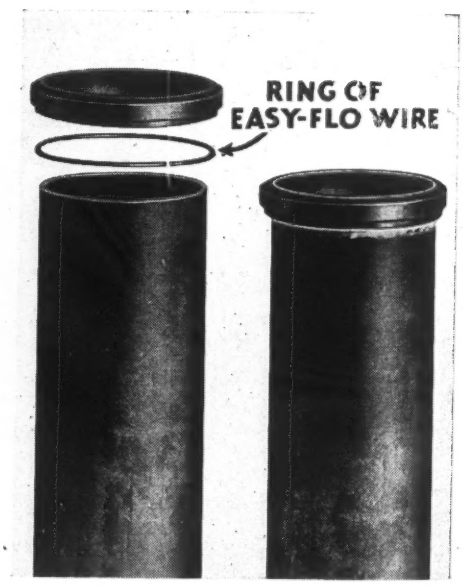


Fig. 9—Shows how preplaced brazing alloy in the form of wire provides just the right amount of material needed

SPECIFICATION of the proper heating method is an important factor in securing strong and economical brazed joints. The method to be used also influences the detail design of the parts, hence should be taken into account at an early stage of the development. Although practically any device that will raise the temperature of the joined surfaces sufficiently can be used, there are limitations and advantages to each of the available methods which narrow the choice in any particular case.

Requirements of the heating system may be briefly outlined as follows: Temperature of both members must be raised above the melting point of the filler but below the melting point or softening point of the parent metal; flame or atmosphere to which joint is exposed should be reducing or provision should be made to prevent oxidation; and parts must be held together firmly in the proper relative position until the alloy has solidified.

Available processes, as classified by the American Welding society, include:

1. Gas brazing
2. Dip brazing
   a. Metal bath b. Chemical bath
3. Electrical brazing
   a. Arc b. Induction c. Resistance
4. Furnace brazing.

Of these possible methods, the last three, namely induction, resistance (*Fig.* 8) and furnace brazing have come particularly to the fore in recent years, although certain of the other processes still enjoy considerable popularity in particular fields.

Gas brazing with a torch using oxygen and acetylene or other suitable fuel gas continues to be the most convenient and universally applicable heating method, especially in the hands of a skilled operator. Control of the heating so as to bring the joint surfaces of both parts simultaneously to the brazing temperature is effected by judicious application of the flame away from the joint. Thus the flame is not allowed to impinge directly on the alloy and the alloy is melted

Utilize Brazing in Design

by the heat of the parts. A neutral or reducing flame is generally used, to avoid oxidation.

Initial cleanliness is of paramount importance, while the use of a suitable flux aids in protecting the metal from oxidation, in dissolving any oxides which may form and in promoting free flow of the molten alloy into the joint. Multiple-flame torches specially designed for particular jobs speed production of joints and when used in conjunction with holding fixtures enable brazing operations to be successfully performed by semi-skilled workers. Because of the high rate of heat loss from parts brazed in the open, torch brazing is seldom used with copper as filler because of the high temperature needed.

Fluxing materials are available in the form of dry powder or paste, and are chosen according to the filler metal and parent metal used. For long the standard material was borax, either in crystalline form or in the amorphous or fused form. Because the crystalline borax contains water of crystallization the application of heat causes it to puff up and roll around, furnishing little protection. The fused borax avoids this condition. Owing to its high melting point (1400 degrees Fahr.) borax is suitable only for use with high melting-point alloys. Also, it does not dissolve certain oxides such as those of chromium, molybdenum, silicon, tungsten, etc., hence is not effective on materials containing these elements.

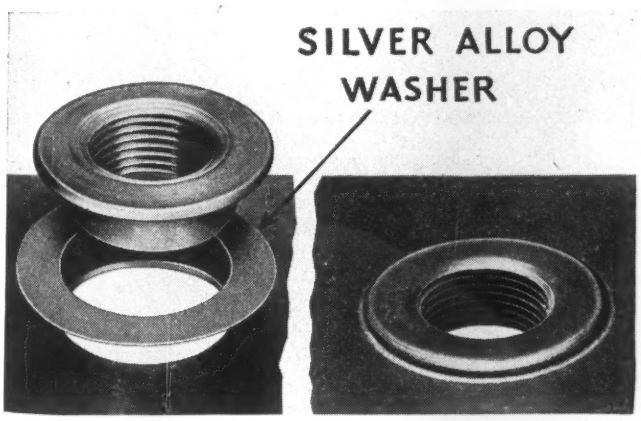


Fig. 10—Preplaced brazing alloy in the form of a washer insures adequate supply of material for a large flat surface

Most fluxes are mixtures of low melting-point materials with active solvent action on refractory oxides. Because dry powders tend to be blown away by the torch before they melt, and will not stick to vertical or overhead surfaces, fluxes in the form of paste often are preferred. Suitable fluxes are furnished by the producers of brazing alloys. It should be emphasized that, although the flux aids in the production of clean joints, it is not a cleaner and its use in no way absolves the operator from strict adherence to high standards of cleanliness. When a flux is used it usually is desirable to clean the parts after brazing, as the residual flux may be hygroscopic, becoming damp and sticky and possibly starting corrosion. Common fluxes are water-soluble and are easily removed by hot water or steam.

Many of the recent developments in brazing techniques have centered around quantity production of parts assembled from stampings, forgings and screw machine products. In the remaining discussion emphasis will

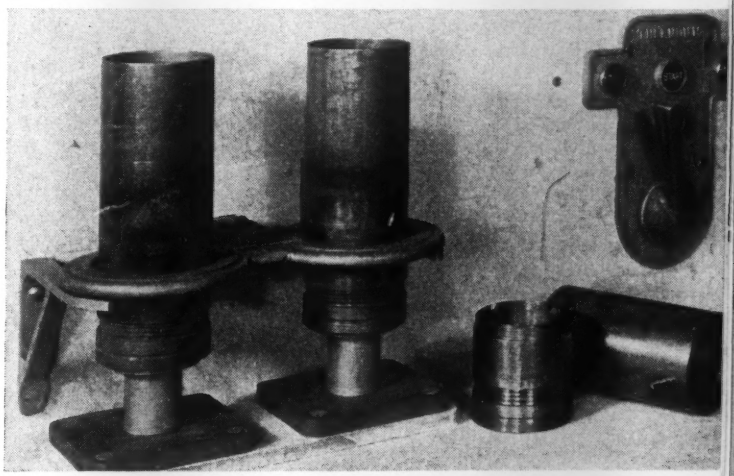
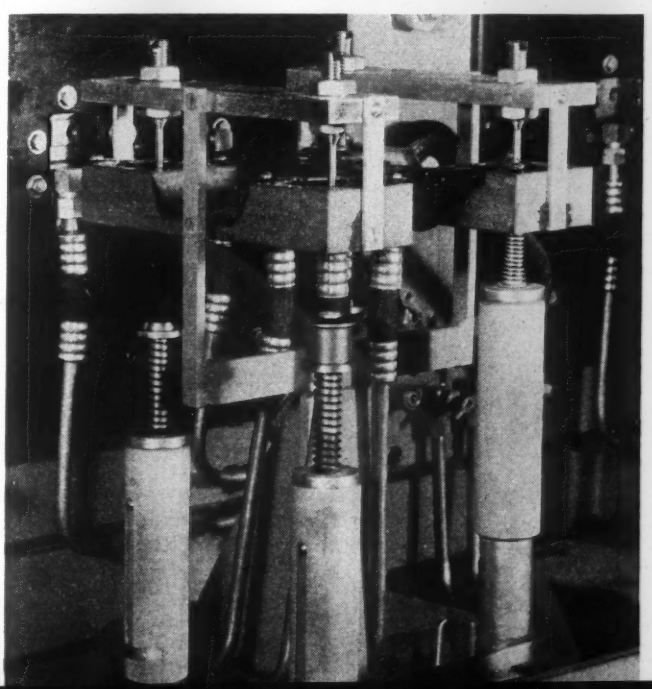


Fig. 11—Above—Set-up for induction brazing of two parts for a 75-millimeter smoke shell confines heating to a comparatively narrow zone

Fig. 12—Below—Brazing cycle for the piston plug cap assembly shown in center is approximately 15 seconds using these induction heating fixtures



therefore be placed on high production methods. Regardless of the method of heating, the two primary factors which contribute most to speedy output of brazed parts are proper selection of alloy form for preplacing in the joint, and the provision of suitable fixtures for quick handling and supporting of parts. Form in which the alloy is furnished—wire, sheet, washers, rings, etc.,—should be such that the material will melt quickly and supply sufficient alloy without excess that may spoil the appearance of the joint or require too much cleaning. Two examples of preplacing alloys in a form suited to the job are shown in *Figs.* 9 and 10. Other forms in which the alloy may be preplaced include spraying, powder and tinning with the alloy by dipping. In addition to expediting production, preplacing also conserves material, insures wetting, acts as a temperature indicator in hand work, and relieves the operator of the responsibility of feeding the alloy.

Designing Parts for Furnace Brazing

Furnace brazing, using oil, gas or electricity as the source of heat, is well adapted to high production of small parts and parts having several individual joints. Because the parts are heated fairly uniformly thermal distortion is practically eliminated. In order to insure uniformity of heating, however, it is necessary to avoid a wide range of thicknesses in the parts. For example, sections only a few thousandths of an inch thick attain brazing temperature in a few minutes, while a half-inch section may require three-quarters of an hour to reach the same temperature. Fast heating is preferred, requiring a high furnace temperature and a time cycle which permits removal of parts as soon as the alloy has completely flowed. Accurate control is essential in all cases but becomes particularly important in the case of material such as aluminum, where the melting point of the filler is close to the melting and softening points of the material. If heating is too slow there may be some interdiffusion of filler and parent metal before actual flow can begin, resulting in a weak joint.

Probably the most important single advantage of the electric furnace is the complete atmosphere control which is possible. In a controlled neutral or reducing atmosphere it is usually unnecessary to employ a flux, though with a few materials such as brass it is still essential. Hydrogen at temperatures above 1500 degrees Fahr. reduces the oxides of copper and of steel, permits the molten copper to flow freely over the steel and alloy with it, and enhances the capillary action so essential to the complete filling of the joint. Because of the expense of hydrogen, furnace design becomes somewhat complicated in the effort to minimize leakage at the entrance and exit. Even a small furnace may use as much as 300 to 500 cubic feet per hour of hydrogen costing upwards of three dollars per thousand cubic feet. A further disadvantage of hydrogen is its decarburizing effect on steel at elevated temperatures, which may necessitate protection such as plating. Efforts have therefore been made to find a satisfactory atmosphere which is less costly than the hydrogen or hydrogen-rich gases hitherto extensively used.

Briefly, the requirements of an atmosphere are simple. It is only necessary to eliminate or greatly reduce the oxygen and water vapor, after which a comparatively small amount of reducing gas will furnish all the protection needed. Such a gas can be produced by the combustion of a carefully controlled mixture of natural and manufactured gases, with subsequent cooling to precipitate the moisture. Cost of such an atmosphere is said to be less than 30 cents per thousand cubic feet. With such a low cost, simpler furnace designs can be employed, since loss of gas within reasonable limits is not a serious cost item.

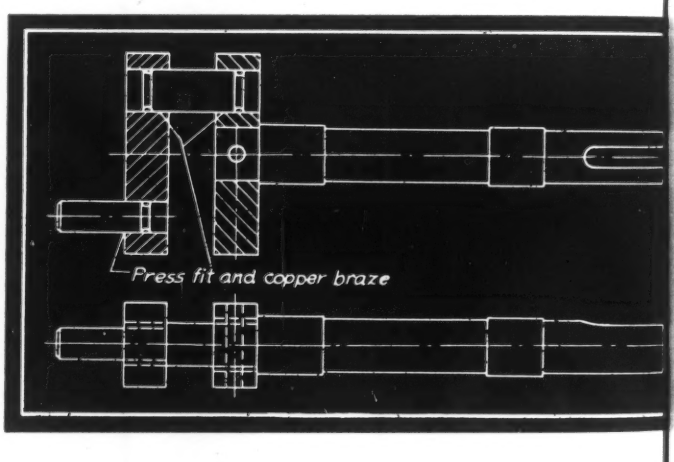


Fig. 14—Two-throw overhung crankshaft assembly consists of two pins and two webs pressed together and copper brazed. Parts are subsequently cyanided

For temperatures up to 1800 degrees Fahr. continuous furnaces employing a belt conveyor of heat-resisting alloy are highly successful. Timing cycle is controlled by the belt speed and is such that the alloy melts when the parts are about three-fourths of their travel through the furnace. For higher temperatures a pusher type furnace is preferred. Because the furnace must also supply heat to raise the temperature of any holding devices used to support the parts, fuel or power costs can be reduced by careful attention to the design of such fixtures or trays. A typical 129-kilowatt furnace will handle 600 pounds per hour of steel parts copper-brazed at 2040 degrees Fahr. operating temperature.

An entirely different approach to the heating problem is found in the induction heating method. By heating

Fig. 13—Overrunning clutch part for automobile engine starter is an assembly of a machined clutch end and a length of tubing copper brazed in an electric furnace

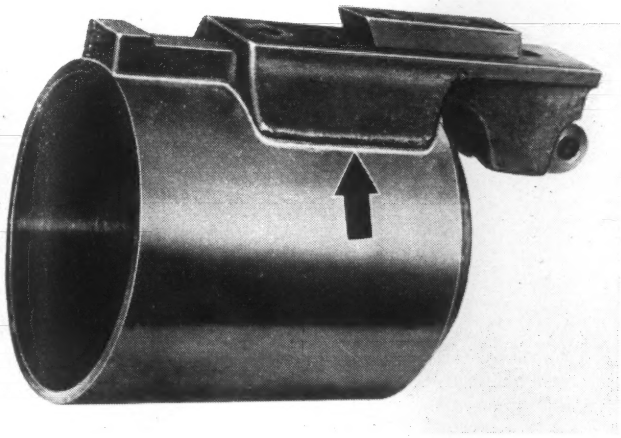


Fig. 15—Above—Part for a tank gun is a silver-brazed assembly on which a gas torch is used as source of heat. Alloy is preplaced in the joint in the form of flat strips

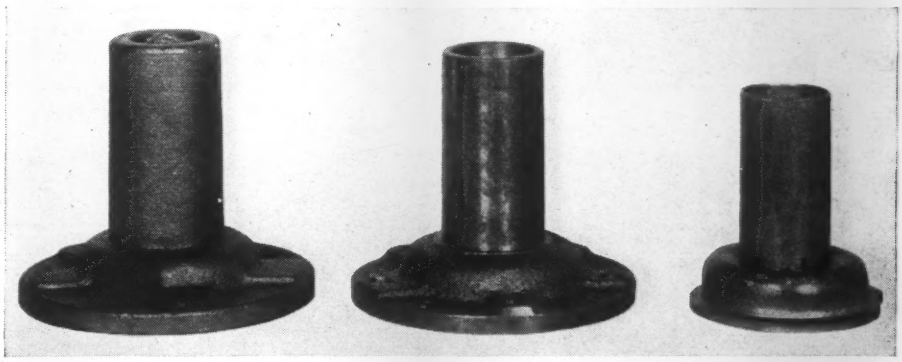


Fig. 16 — Right — Furnace-brazed clutch-gear bearing retainer, right, replaces malleable iron part and weighs only one-third of the machined part at center

only the part of the metal adjacent to the surfaces to be brazed, the cost of heating is greatly reduced. Because induction heating does not depend on conduction of heat through metal and through surface films, it is extremely fast and can therefore be highly localized, preserving the physical properties of adjacent sections and avoiding scaling or even discoloration. With accurate control and automatic timing, uniform results are easily obtainable with unskilled operators.

Induction heating depends for its effect on the creation of eddy currents the resistance losses of which are proportional to the square of frequency and to the square of current in the field-producing conductor, while in the case of magnetic materials there is also the hysteresis effect due to molecular friction, which is proportional to frequency. Because nonmagnetic materials depend solely on eddy current effect and usually are good conductors, it will be apparent that a strong magnetic field and a high frequency are necessary. Thus the customary 60-cycle power supply is inadequate and a frequency converter is necessary.

Sources of High-Frequency Current

Rotary electric generators are used to furnish frequencies from 3000 up to 15000 cycles per second. They are available in high capacities, up to 250 kilowatts, and are of simple mechanical construction offering few maintenance problems. Terminal voltages need not be high, due to the low impedance of inductive loads.

Where higher frequencies are needed to intensify the heating effect, resonant spark-gap circuits delivering up to 200,000 cycles per second are available in capacities up to 15 or 20 kilowatts. Still higher frequencies, which may go as high as 5,000,000 cycles per second, are furnished by vacuum-tube oscillator circuits. Although the kilowatt capacity of this type is limited, the local heating effect may be intense due to the high frequencies possible. Maintenance is simple and no adjustments are needed to maintain the desired frequency.

The high-frequency field is furnished by a coil consisting of one or more turns of copper tubing surrounding but not touching the part to be brazed. Single coils are used to provide a narrow localized heat pattern while multiple coils are used where a larger area must be heated. Both may be designed to fit the contour of the work and are adaptable to complex shapes. Because the strength of the field and therefore of the heating effect is inversely proportional to the square of the distance from the conductor, the coil should not be too close to corners and sharp edges of the work lest burning occur.

In brazing a thin-walled object to a heavier part, the set-up is so designed that the thick wall is heated first, thus preventing overheating of the thinner section. In all cases the aim is to bring the two parts up to the brazing temperature at the same time. Typical production set-ups for induction brazing are shown in *Figs.* 11 and 12.

Provides Fast Heating Time

Electric resistance brazing utilizes heat generated either in the parts to be joined or in the electrodes, from which it is conducted to the material in the vicinity of the joint. The latter method, known as incandescent carbon brazing, *Fig.* 8, is more widely used than the former. As in the case of induction heating, heating time is fast (½ to 3 seconds) and the high temperature is localized. The source of power is a transformer which furnishes high-amperage low-voltage current and the only other equipment necessary comprises brazing tongs, electrodes, leads and control switch, all of which can be portable. Electrodes generally are carbon, or may be of tungsten or a high-tungsten alloy backed by water-cooled copper. Strong joints may be produced because the heat is applied under pressure, the pressure being maintained until the alloy has solidified.

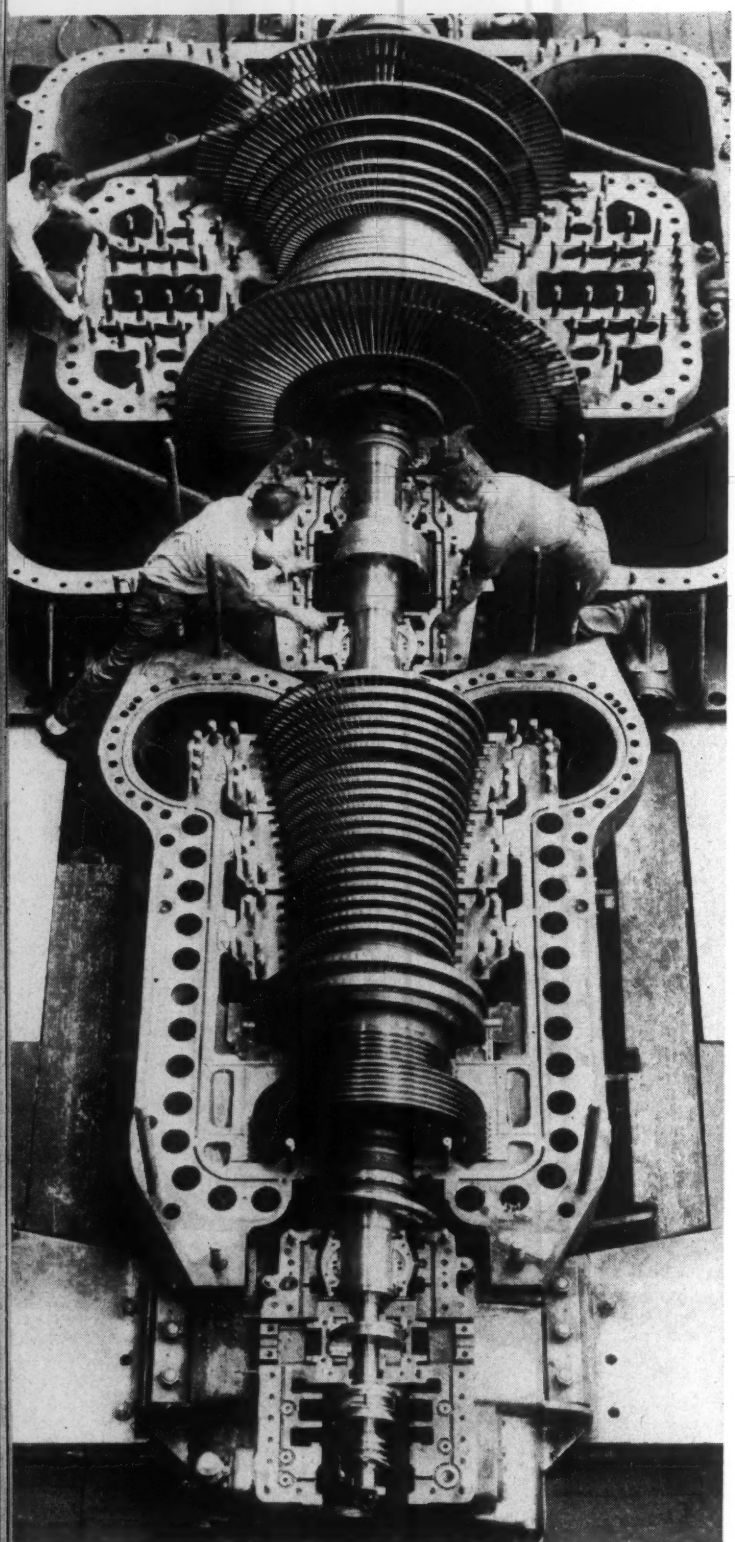
In dip or bath brazing the parts to be joined are immersed in a molten bath of filler material (metal bath) or of a salt which acts as flux (chemical bath). The method has the advantage of quick heating of the whole piece

(*Continued on Page* 198)

Calculating Beam Deflections

By C. L. Brown

Purdue University



Photo, courtesy Westinghouse Elec. & Mfg. Co.

***Fig. 1**—In large shafts, such as are used on steam turbines, deflections under load may seriously affect clearances*

IN THE design of beams and shafts loaded in bending the calculation of deflections, often an essential determination, can be greatly simplified by the adoption of a suitable working approximation. For most purposes requiring a knowledge of deflections, such as vibration and critical speed calculations, and where small clearances are involved, the accuracy of the results is entirely satisfactory.

Of the several methods which have been devised to determine deflection curves, the best known is the integration of the differential equation of curvature. This is readily applicable to beams of constant cross section, even with several loads, since the principle of superposition may be applied. If, however, the beam has a section that varies along its length the mathematical integration becomes extremely complex. In cases of this sort other methods are usually applied, the most common being integration by graphical means or the conjugate beam method.

***COMPLEXITY** of rigorous methods often is a handicap to speedy determination of beam and shaft deflections. Presenting a simplified method, this article tells how reliable results can be obtained with considerable savings of time and effort*

Approximate Method Saves Time

Both of these involve much labor and any shortening of the required time is a worth-while saving. An approximate method can be developed by the application of the calculus of finite differences, which is considerably less laborious and which yields accuracy fully as good as that of the graphical integration method.

For the deflection of a beam the fundamental differential equation is

$$\frac{d^2y}{dx^2}=\frac{M}{EI} \qquad (1)$$

where the bending moment M, the moment of inertia I, and the elastic modulus E all are functions of x. y is the deflection at a point x along the beam. Almost always, E is constant and it will be so considered here, but a variable E can be handled as well as a variable I.

The first derivative in finite differences, *Fig.* 2, is the

rate of change of y, or

$$\frac{y_{+1}-y_0}{\Delta x}$$

Similarly, the second derivative is the rate of change of the first derivative:

$$\frac{\frac{y_{+1}-y_0}{\Delta x}-\frac{y_0-y_{-1}}{\Delta x}}{\Delta x}=\frac{y_{+1}-2y_0+y_{-1}}{\Delta x^2}$$

If this is substituted in the differential equation, Equation 1, then

$$\frac{y_{+1}-2y_0+y_{-1}}{\Delta x^2}=\frac{1}{E}\left(\frac{M}{I}\right)_{x_0} \quad \ldots\ldots (2)$$

which may be written:

$$y_{+1}=2y_0-y_{-1}+\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_0}$$

or, in general terms

$$y_{n+1}=2y_n-y_{n-1}+\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_n} \quad \ldots\ldots (3)$$

Beginning at a support, it is known that the deflection there is zero but further progress cannot be made until the deflection of the adjacent point is found. From Equation 3,

$$y_2=2y_1+\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_1}$$

$$y_3=2y_2-y_1+\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_2}$$

$$=3y_1+2\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_1}+\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_2}$$

or, in general

$$y_n=ny_1+(n-1)\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_1}+(n-2)\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_2}+\ldots$$

$$\ldots.+\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_{n-1}} \quad \ldots\ldots (4)$$

If the nth point is at another support, $y_n=0$ and Equation 4 may be solved for y_1.

The beam shown in *Fig.* 3 illustrates the method. Divisions were chosen so that $\triangle x=3$, then

$$\frac{\Delta x^2}{E}=\frac{3^2}{30\times10^6}=3\times10^{-7}$$

The first step is to compute the values of I and M at each point and tabulate the results as in TABLE I. For example, at point 1 the shaft diameter is 3.2 inches, hence $I=\pi d^4/64=\pi\times3.2^4/64=5.15$ inches^4. Also, the bending moment is $M=3600\times3=10{,}800$ inch-pounds. If a division point falls at a change in shaft section, the I used should be the average of the two on either side (points 3 and 7). Thus, for the 4-inch diameter $I=12.55$ and for the 6-inch diameter $I=63.5$, the average being 38 inches^4. Now y_1 is calculated using Equation 4, which may be written:

TABLE I

Computation of Beam Deflection

n	I_n	$M_n\times10^{-3}$	$\frac{\Delta x^3}{E}\left(\frac{M}{I}\right)_{x_n}\times10^4$	$y_n\times10^4$
0	.....	0	0	0
1	5.15	10.8	6.3	—20.8
2	10.25	21.6	6.33	—35.3
3	38.0	31.2	2.46	—43.5
4	63.5	39.3	1.86	—49.2
5	63.5	47.1	2.23	—53.0
6	63.5	42.8	2.02	—55.6
7	38.0	38.7	3.05	—56.7
8	12.55	30.6	7.32	—54.7
9	12.55	20.4	4.88	—45.4
10	3.98	10.2	7.68	—31.2
11	.....	0	0	— 3.9

$$y_{11}=11y_1+10\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_1}+9\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_2}+\ldots.$$

$$\ldots.+2\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_9}+\frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_{10}}$$

But $y_{11}=0$, therefore

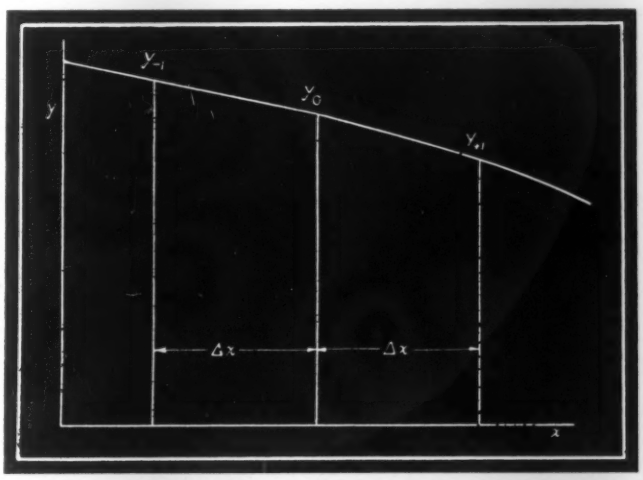


Fig. 2—Portion of deflection curve shows how finite differences are defined

$$0=11y_1+(10\times6.3+9\times6.33+8\times2.46+7\times1.86$$

$$+6\times2.33+5\times2.02+4\times3.05$$

$$+3\times7.32+2\times4.88+7.68)\times10^{-4}$$

$$y_1=-20.8\times10^{-4}$$

The remaining y's may be calculated from Equation 4 if

desired or, more easily, from Equation 3. The latter method was used in setting up the table. Sample calculations follow.

$$y_2 = 2y_1 - y_0 + \frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_1}$$

$$= -41.6\times10^{-4} + 6.3\times10^{-4}$$

$$= -35.3\times10^{-4}$$

$$y_3 = 2y_2 - y_1 + \frac{\Delta x^2}{E}\left(\frac{M}{I}\right)_{x_2}$$

$$= -70.6\times10^{-4} + 20.8\times10^{-4} + 6.33\times10^{-4}$$

$$= -43.5\times10^{-4}$$

Values y_4 to y_{11} are calculated in a similar fashion. Note that y_{11} does not equal zero. This is a cumulative error which, if it is objectionable, may be distributed as shown on *Fig.* 3, or avoided entirely by using Equation 4. The tabulated calculations were made on a slide rule and the error is due to the use of only three significant figures. If computations had been made on a calculating machine this error would have been eliminated.

The degree of accuracy obtainable is dependent upon the number of changes in diameter of the shaft and the number of divisions used. For a shaft of constant diameter or a tapered shaft an accuracy of ±5 per cent is attainable with as few as five divisions. A stepped shaft requires more, the number depending upon the number of abrupt changes in diameter.

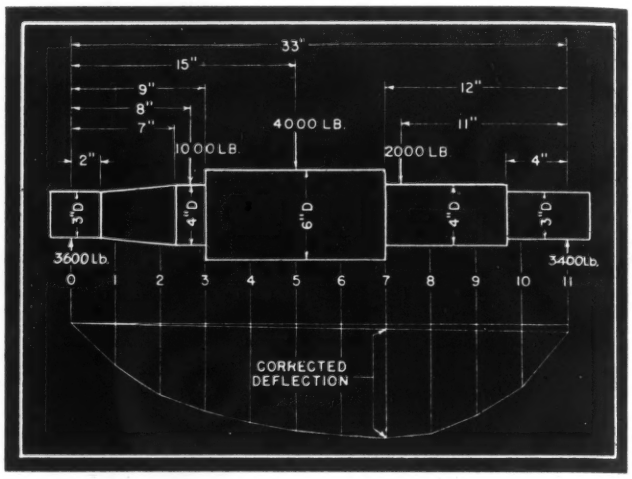


Fig. 3—Stepped shaft under load deflects as indicated by approximate elastic curve in lower part of illustration

Heat Treating Cast Iron for Wear Resistance*

LATHE beds and carriages may experience two distinctly different types of damage. Either they may wear, losing material gradually from their rubbing surfaces until the accuracy of the lathe is lost, or they may gall, material being torn out of one surface in small pieces and welding to the other, causing deep gouging.

Wear is generally due to either abrasive or lack of lubrication. Two types of abrasive which cause most lathe-bed wear are scale from heat-treated steel and dust from cast iron. Both are brittle enough to crush small particles that get trapped between the rubbing surfaces and are hard enough to cause wear.

Galling, or scoring is induced by "short-stroke" work in which the carriage moves back and forth many times over a short distance on the bed.

No metals seem capable of resisting this type of failure indefinitely, even at minute loads, when the stroke is short. However, metals vary in their ability to resist scoring for a longer stroke, and it is desirable that the best be selected.

Investigation of the effect of composition of cast iron on performance showed that increase of the carbon content or small changes in the alloy content do not greatly change the rate of wear or the scoring load, so long as the iron is fully pearlitic. Ferritic irons must be avoided or rapid wear and scoring will be experienced. Low-carbon irons too must be avoided, because one fully pearlitic iron with only 2.53 per cent carbon scored at an extremely low load. High-alloy irons, containing considerable amounts of free carbide, wore a little more slowly and scored at somewhat higher loads, but they were expensive and extremely difficult to scrape because the many carbide particles dulled scrapers with extreme rapidity.

Heat-treatment was then tried as a means of obtaining the desired improvement. From furnace heat-treating experiments, it was found that better results were obtained by cooling comparatively rapidly from above the critical temperature, to produce an extremely fine pearlitic structure, than by quenching and drawing to the same hardness to produce a sorbitic structure.

The experiments were extended to sections of beds, and it was found that the desired structure and wear resistance could be obtained by heating the surface with a flame-hardening torch to above the critical temperature, depending on the heat drain from the cooler interior of the bed to produce the proper rate of cooling. It was found that the temperatures of the underlying bed must be somewhat elevated, by making a preheating run with the torches, to prevent too rapid cooling and excessive hardness. This process is called "flame refining" (patent applied for) to distinguish it from flame hardening where a quench is essential and full hardness is desired. By experiment, it was found that these heat-treated irons could be scraped at hardnesses up to 30-35 rockwell C if carbide-tipped scrapers were used.

Wear and scoring tests of these heat-treated irons showed that abrasive wear was only 70 per cent as great as that of the same irons before heat treatment, and that the scoring load was 50 per cent greater than for the same irons not hardened. The heat-treating process performs even more strikingly on ferritic irons, which is to be expected since the flame-refining process eliminates free ferrite from the structure.

*From a paper by R. W. Dayton, C. H. Lorig and R. E. Adams, Battelle Memorial institute, presented at the recent annual meeting of the A.S.M.E.

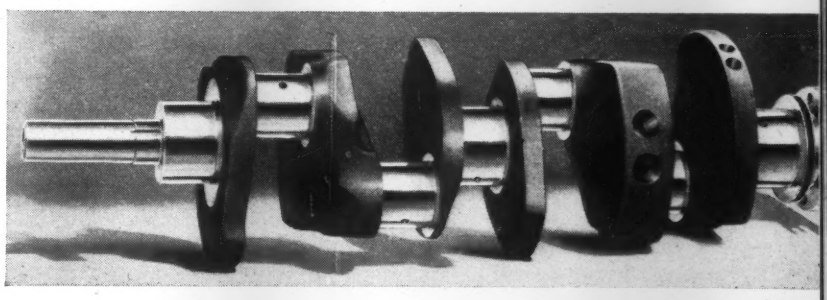


Fig. 8—Specimens cut from heavy sections of the Ford V-8 cast crankshaft show zero elongation in the tensile test and one foot-pound Charpy impact resistance

Choosing the Right Material

Part II—Interpreting Tests*

By H. W. Gillett

War Metallurgy Committee

WHETHER or not a test appraises the adequacy of a material for specific engineering use depends on whether the design engineer can put his questions in terms like pounds per square inch and whether the testing engineer can give his replies in the same terms. Unless each can and does this, the only recourse is to the automobile proving ground type—or the simulated service type—of test.

Simulated service tests are necessary when the kind, distribution and intensity of stresses applied in service are not known; when unknown and fluctuating temperatures are met or when special corrosive atmospheres of variable composition are concerned. Resorting to simulated service tests is a confession of ignorance about the fundamental factors of service or of the relative importance of these factors. But it is far better to confess ignorance and proceed to acquire information, than to specify by guess. Simulated service tests are, however, often applied more as a matter of psychology than of technology, for the assurance they give the executive that the engineer hasn't slipped somewhere.

From the standpoint of the testing engineer, descriptions of service requirements phrased in pounds per square inch, presumably can be met by straightforward testing, those not so phrased can be answered only indirectly, if at all. It is such considerations that lead the aircraft engineer to plaster sensitive, short-length strain gages all over the airplane and its component parts in order to get a record of what the service stresses really are.

In a way, hardness data "pounds per square inch". A hardness test does tell considerable about "pounds", and a series of hardness indentations tells a lot about uniformity of the "square inches"; hardness tests will also tell much about uniformity of materials and of final parts from lot to lot. Thus, in testing armor plate, one plate in 100 may be subjected to a firing test, the other 99 may be checked for hardness.

Hardness has strong connotations about machinability, but a hardness value is not itself directly usable in design because, like tensile strength, it involves deformation far beyond what can be allowed in service.

Determination of Yield Strength

The primary criterion of load-carrying ability is yield strength—the unit load that can be carried without appreciable permanent deformation—so that when the load is released the piece returns to its original, unloaded, dimensions and position. Yield may be determined in tension, compression or torsion, depending on how the load is to be applied in service. Tension testing is the easiest, and is usually adequate because steels have about the same yield strength in compression as in tension. Cast iron is much stronger in compression than in tension but, for any given type of alloy, the compressive and torsional yield strengths are usually so directly proportional to the tensile yield

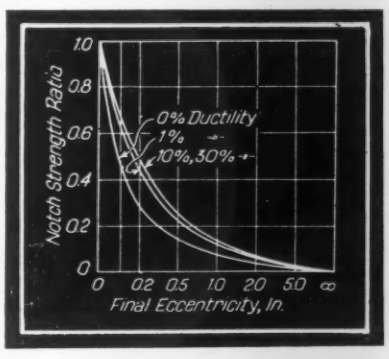


Fig. 9—Theoretical relation between notch strength ratio and final eccentricity of material

*This continues the abstract from a War Metallurgy Committee report, Part I of which appeared in the December issue.

strength as to be sufficiently indicated when it is known.

Yield strength is a directly usable, engineering design criterion of static load-carrying ability. It supplies the universal language for appraisal of load-carrying ability of any material. Next to hardness, it is the test most universally made. Much engineering design is ostensibly based on tensile strength rather than yield strength because, in a given class of the older materials of engineering, the ratio of yield to tensile strength is fairly constant, so either figure served equally well. This is no longer the case. Many of the newer materials, especially heat-treated and alloy steels, have much higher yield strengths than would be expected by applying the old ratio to their tensile strengths, so the design basis has shifted to that of yield strength.

The amount of permanent deformation which a specimen is allowed to undergo, before the yield strength is considered to have been reached in the test, is usually .02 per cent, to facilitate testing, since the factor of safety ordinarily insures that the design load, calculated from the yield strength, is enough lower so that such a material has no permanent deformation in service. Where closer values are needed a smaller permanent set, e.g., .002 per cent, is used.

With adequate knowledge of the load-carrying ability required by the intended service, and adequate testing to insure that the material used has that load-carrying ability, there would be no need for a generous "factor of safety". The required load-carrying ability is, however, calculated, for tensile stresses, on the assumption of axial loading, uniform loading over the whole cross section. Such loading is hard to secure in practice, the load at some point on the exterior of the piece is higher, by an

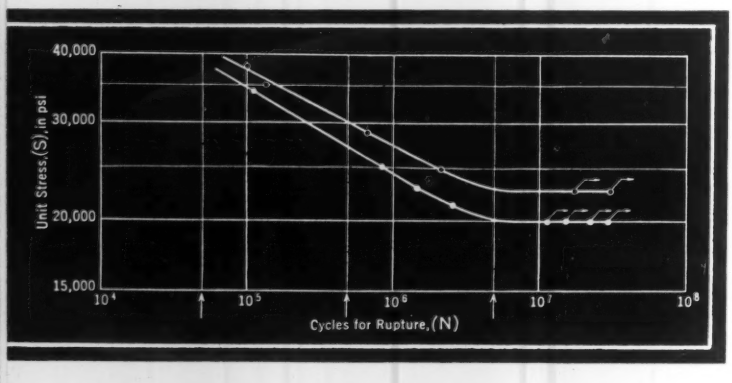


Fig. 10—Stress vs. number of cycles for rupture on two railway axle steels. Arrows denote unbroken specimens

uncertain amount, than the calculation. The factor of safety is often really intended to take care of this more than of the other unknown factors.

The yield strength test gives pounds per square inch, but it is important that the "square inch" represents what it is supposed to. Tensile tests of heat-treated steels are generally made on specimens roughed out almost to size, with only a final grinding allowance, i.e., they are heat-treated in about .505-inch diameter specimens. In such sections many steels are fully hardenable that are not hardenable in larger section. The yield strength values obtained on the small section are only true for the large section when the large section itself hardens clear through.

Besides this, heavy sections of any sort, heat-treated or not, are likely to be softer at the core than at the outside. Hence, yield strength figures need scrutiny to be sure that they truly represent the whole, or that part of the cross section in which we are interested.

In the course of the determination of yield strength, it is possible to determine the modulus of elasticity, i.e., the reciprocal of the elastic deformation per unit stress. There is little need for routine determinations of modulus. All steels, nearly up to their yield strength, have closely the same modulus of elasticity, the same springiness. It is the yield strength that determines the range within which a steel spring can be loaded, for, whether it has a high or a low yield strength, the modulus of steel comes in the range 27 to 31 million pounds per square inch. Composition and heat treatment are not factors that influence modulus to any noteworthy degree.

Determination of Tensile Strength

If the pull on the specimen used for measuring yield strength is kept up, the specimen starts to yield, to deform permanently, and finally breaks. The maximum load withstood up to fracture, divided by the original area, before deformation, gives the tensile strength.

Cases where the engineer uses tensile strength directly are almost as rare as hen's teeth. Complete rupture in engineering applications only occurs in protective devices, such as shear pins, fuses, bursting disks and the like, or in such things as high-explosive shells. Everywhere else, the engineer designs for life, not for failure. In cast iron and a few nonferrous alloys and in fully hardened, untempered steel, there is no true yield, the tensile being very little above the yield. Engineering steels and nearly all engineering nonferrous metals have a considerable gap between yield and tensile strengths, a range of plastic action. This plastic action is utilized in cold-forming; it is not utilized in normal service of a completely finished part, save as possible insurance against shattering failure when an accident occurs.

Ductility Determinations

Ductility values, elongation and reduction of area, determined in the course of carrying the yield strength test to fracture, are not in pounds per square inch, they are in per cent of the original length or area. The engineer does not and cannot use the figures in design. The fabricator does not and cannot use them directly to appraise ability for cold forming. Both use them only in indirect fashion, for what they connote rather than what they state.

They do not directly measure toughness. The stress-strain diagram plotted from a tensile test gives two areas, one that of energy absorbed during elastic deformation, depending only on the modulus and the yield strength, and second, that of energy absorbed during plastic deformation.

This area is a quantitative measure. The elongation and reduction of area figures give only an inkling of the area. Even the area under the stress-strain diagram tells nothing about the "notch sensitivity" of the material, it defines "toughness" only in a qualitative sense. The ductility figures do give a rough idea of the reserve of plas-

ticity available for insurance against shattering fracture.

Sachs, Lubahn and Ebert[1] present data on the small degree of deformation required under eccentric tensile loading, to permit a notched tensile bar of steel to give without cracking and thus to eliminate the eccentricity of loading before failure ensues. They say that evaluation of a steel based on the very high values of contraction of area in regular tensile tests is entirely misleading; the "notch ductility" represents the practically useful ductility. This notch ductility as they define it is not based on elongation, but on per cent contraction of area *at the root of the notch.* A strain of less than 2 per cent, thus measured, they consider sufficient almost completely to eliminate the effect of stress concentration on the fracture stress. However, notch-base-contraction of less than 2 per cent can accompany a 50 per cent contraction on an un-notched tensile bar.

They propose testing by controlled eccentric tensile loading of a notched bar. Without taking space to discuss the test details or the meanings of the coordinates, one of their figures is shown as *Fig.* 9, to bring out the wide difference between a steel with no notch-base-contraction, i.e., one that behaves brittle, and one with one per cent notch-base-contraction which behaves with almost the same toughness as does one with ten per cent. Moreover, after deformation has taken place it is not possible to distinguish between steels that, pulled without eccentricity, show 10 or 30 per cent notch-base contraction.

The same sort of behavior has been found with magnesium alloys at very low temperatures, a surprisingly small amount of plastic flow, around one per cent, sufficing to allow a tough rather than a brittle fracture under static tensile stress.

Jackman[2] remarks that many aircraft structural designers believe that 3 to 5 per cent tensile elongation in certain aluminum alloys is adequate for most design conditions. In an examination of conditions in the 24ST and Alclad 24ST skin and flanges of an actual wing, Koegeler and Schnitt[3] show that structural failure ensues from excessive permanent deformation that uses less than 1½ per cent tensile elongation and comment on the contrast between this figure and the 10 to 14 per cent elongation inherent in the material but "never attained" in service.

Triaxial Loading

Some writers argue that because triaxial stresses tend to reduce the ability of a metal to undergo plastic flow, a large degree of tensile ductility should be present to allow more plastic action. The weakness of this argument lies in the fact that large tensile ductility does not insure against poor plastic behavior under triaxial loading. Copper, extremely high in tensile ductility, is nevertheless quite notch-sensitive. The rate at which a metal cold works, becomes strengthened, and passes on the load so that the load becomes distributed over a larger volume, plays a considerable part in its behavior. So many factors, acting at the same time, control the behavior of a metal seeking to flow under triaxial stresses that such behavior of that metal is not adequately revealed in the ordinary tensile test.

Direct testing under the complex loading conditions of service on the actual part, in its actual size and contour, needs to be resorted to rather than to assume that a taffy-like behavior under a straight pull on a smooth, round bar, is necessary.

Some writers also are vastly impressed by small differences in reduction of area, feeling that ability to flow locally is surely reflected by these values. The percentage reduction of area figures rather emphasize the actual deformation. At 25 per cent reduction of area a .505-inch diameter bar necks down to .437-inch, at 15 per cent to .465-inch. Even at 5 per cent, it necks down to .492-inch. Stainless steel, manganese bronze, and various other alloys do not neck much, the decrease in cross section resulting from general, rather than local, thinning down. Under the approach to triaxial stressing produced in a standard notched-bar impact test, these materials act tougher than many that show great local necking in the ordinary tensile test.

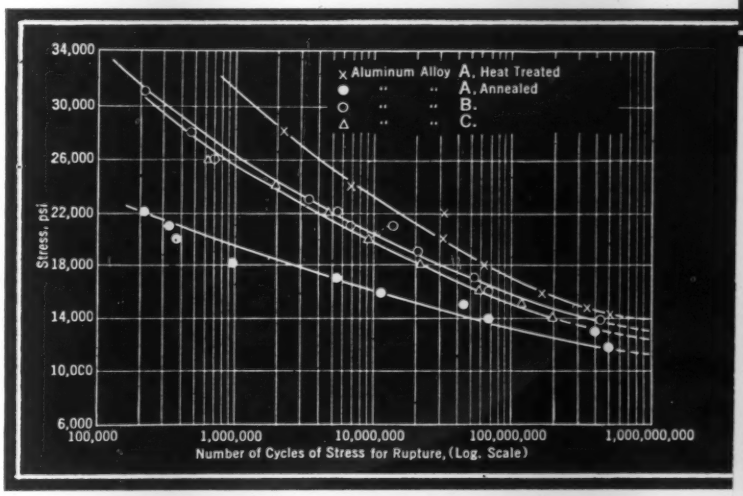


Fig. 11—Stress vs. number of cycles for rupture on aluminum alloys. All specimens were broken. The S-N curves do not show an endurance limit for aluminum alloys

Osgood[4], speaking of normal adjustment to tensile stress as "accident insurance", remarks that it is the stretching *prior* to necking that counts and advocates noting the general elongation, exclusive of that in the necked portion.

In considering local plastic deformation in relation to formability, as in making a sharp bend, some authorities emphasize local elongation (in contrast to the point of view taken by Osgood in respect to stress adjustment) and point out that in very strong materials whose elongation in a 2-inch gage length is very low, there may yet remain large ability for deformation over the short length actually involved in bending, so that abilities for general and for local deformation do not necessarily go hand in hand. Hence engineering interpretation of elongation figures cannot be soundly made without differentiating between general and local ductilities.

Riegel and Vaughn[5] cite a case of two steels of identical

[1] Sachs, G., J. D. Lubahn and L. J. Ebert—"Notched-Bar Tensile Test Characteristics of Heat-Treated Low-Alloy Steels", *Preprint* No. 26 for Oct. 1943 meeting American Society for Metals. This discusses only static, not fatigue, behavior of notched specimens.

[2] Jackman, K. R.—"Super Aluminum Alloys for Aircraft Structures", *Aviation*, Aug. 1943, Pages 154-158, 163, 297-305.

[3] Koegeler. R. K. and A. Schnett—"Effects of Yielding and Perforations on a Wing Tension Surface", *Journal Aeronautical Sciences*, Vol. 10, Oct. 1943, Pages 273-284, 321.

[4] Osgood, W. R.—"Symposium on Significance of the Tension Test of Metals in Relation to Design", Page 584, Reprint from 1940 *Proceedings* A.S.T.M.

tensile and yield strengths, elongation and reduction of area, (45 per cent) which gave, in the approach to triaxial loading of the notched bar impact test, 12 to 16 foot-pounds for one steel and 2 to 4 for the other, and comment that this indicates the futility of attempting to predict notch-toughness from the figures given by the ordinary tensile test or even from the area under the stress-strain curve[5].

That ductility itself is of minor engineering importance in a finished structure; that the benefits ascribed to it come largely from the work hardening accompanying severe deformation; and that tensile test methods might be elaborated to give information on work-hardening propensity or other more direct tests used to evaluate it—are brought out in a discussion by O'Neill[6]. He emphasizes that there is "more promise in using quantities which embrace work-hardening properties than in searching for a single value which only represents one point on the deformation curve". Thus, even from the point of view of fabrication requiring plastic flow, the tensile ductility figures, elongation and reduction of area, are appraised as insufficient and incompetent to tell a complete and true story. Work hardenability may not be the same under polydimensional straining as it is in tension.

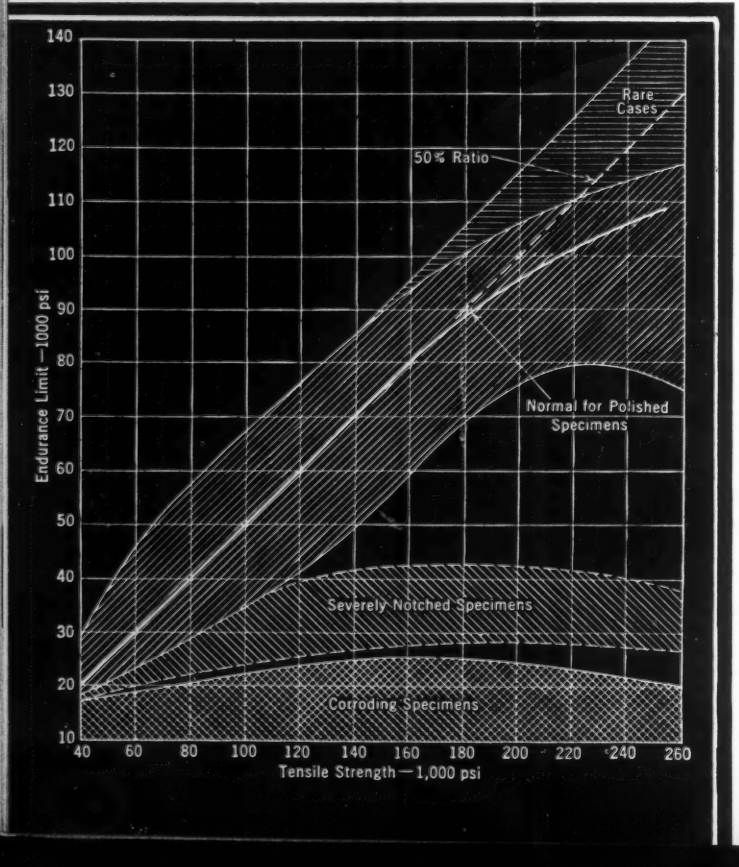
The usual "property charts" for 4340 or any other alloy steel at 115,000 pounds per square inch yield show 65 per cent reduction of area on a *longitudinal* section. It is well known to metallurgists, though seldom emphasized to designers, that different heats may all show 65 per cent reduction of area on a longitudinal specimen, but vary in transverse specimens from 65 down to half that figure.

It is only because ductility values are regularly secured as a by-product of the directly valuable yield strength determination and thus are available in quantity, that we tend to use them as indirect criteria of quality, when they do not at all measure the quality we need. This familiarity with the normal, usually far superabundant, ductility of the material formerly used, is likely to influence our thinking in respect to a substitute and to make us reject, without trial, adequate materials of lower ductility. When we free ourselves from these false limitations, we are more likely to think of such substitutions as the Ford cast crankshaft, *Fig.* 8, and the glass gage. Zero ductility is acceptable in the actual service of both.

[5] Riegel, G. C. and Vaughn, F. F.—"Practical Application of the Notched-Bar Impact Test", *Proceedings* A.S.T.M., Vol. 35, Part 2, 1938, Pages 60-66.

[6] O'Neill, H.—"Significance of Mechanical Test Properties of Metals", *Engineering* Vol. 156, July 2, 9 and 16, 1943. Pages 18-20, 38-40, 56-58.

Fig. 12—Diagrams indicating the general behavior in fatigue of steel of polished, notched, or corroding specimens, in relation to the tensile strength



Resistance to Repeated Stress

As important as the knowledge of yield strength is the endurance limit. Under repeated stress, failure may occur, in apparently brittle fashion, at stress levels well under the yield strength, and without measurable deformation. The nucleus of failure is usually at the surface, and the fracture shows oyster-shell markings. The mechanism of failure is progressively a damaging action, formation of a crack as a result, and speedy propagation.

The nucleus of failure is almost invariably some sort of a stress-raising notch, or poor fillet, whose avoidance comes within the field of the designer, or an accidental nick or a roughness of the surface from the type of machine-shop finish used. Mere weakness of the surface, due to decarburization, often plays a part in steel.

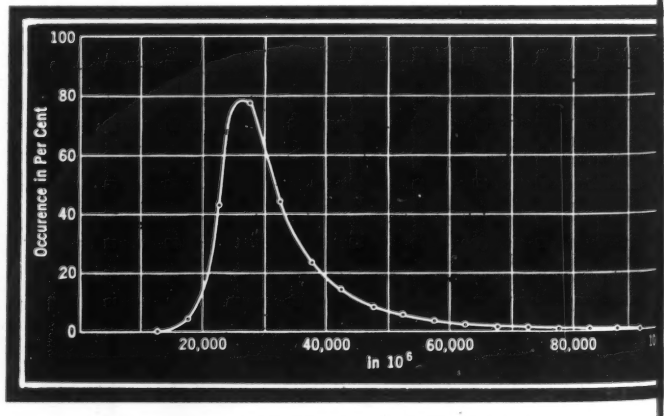


Fig. 13—Distribution curve for number of cycles to fracture at 45,500 pounds per square inch

Two opposing factors operate during repeated stress, one the damaging action that finally results in cracking, the other a cold-working action that strengthens the material. The strengthening effect is evident in a notched-fatigue test of annealed 18-8, which work hardens readily. A notched bar of this material shows a higher endurance limit than a polished, un-notched bar (contrary to the behavior of ordinary steels) because of the local work hardening at the base of the notch. It has "crackless plasticity."

In general, endurance against repeated stress, on polished bars, rises as the tensile strength increases, though, as is particularly evident in the case of some aluminum alloys, it is always true that the stronger the alloy the higher its polished-bar endurance.

In ordinary steel, however, there is a rather close rela-

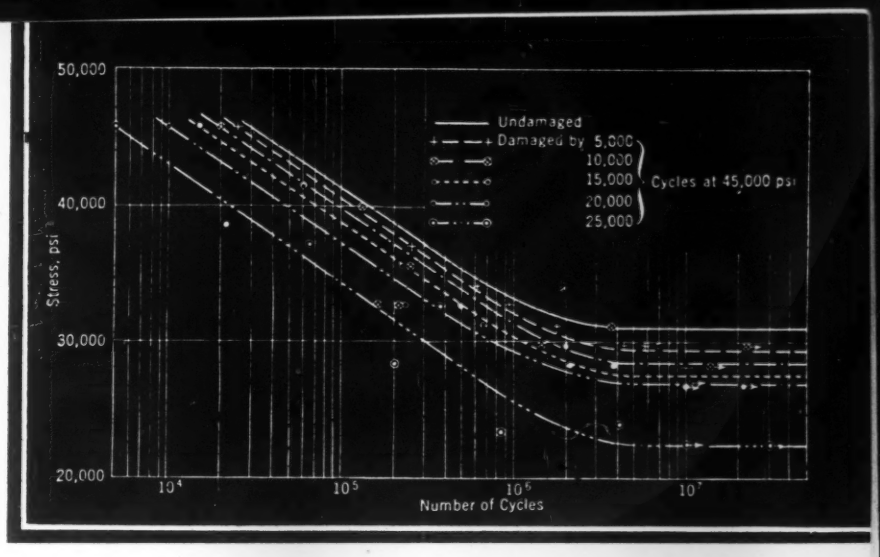


Fig. 14—S-N curves for specimens damaged in test of Fig. 13

tionship between tensile strength and polished-bar endurance, but in notched-endurance the stronger steels are much more easily damaged, they have too little ability to be cold worked without cracking, and are more notch sensitive in fatigue.

"Cloud-burst hardening" or shotblasting to peen the surface of springs, etc., or the cold working of the surface of a shaft by rollers under pressure, the pressure-rounding of the lips of oil holes by a suitable tool, and working the bases of the notches in threads, keyways, splines, etc., by special tools, are expedients that are proving highly effective in improving the surface resistance to fatigue. The surface is almost invariably the vulnerable location. But in all such expedients great care has to be taken not to over-cold-work and thus do more damage than good. Evaluation of just what constitutes excessive cold work would be much worthwhile. There are methods for control of the shotblasting operation, so that a like degree of cold work can be applied day after day, but proof of just what degree is best requires recourse to fatigue tests.

Strengthening of the surface by case hardening, nitriding, local flame hardening or induction hardening are analogous means for combatting fatigue failures. In the case of shotblasting, surface compression stresses are produced that may act in analogous fashion to the introduction of stress in auto-frettage of a gun, and discussion rages whether it is the hardening or the compressive stress that is the more potent. To the designer it is enough that the result is beneficial, whatever the theory involved.

At very high repeated stresses excessive local cold working and the production of incipient cracks will occur in time, just as happens in ordinary cold-working processes where over-cold-working has to be avoided. At low stresses, the cold working may be beneficial. The phenomenon of "strengthening by under-stressing", i.e., a raising of the endurance limit by running at repeated stresses slightly under the endurance limit, is very marked in most metals.

The stress level at which strengthening by under-stressing is so potent that the material will last for an indefinite number of cycles, is the endurance limit. Steel has a real endurance limit; if never stressed above that level it would last forever, as far as can be determined. In most nonferrous alloys there is no such sharp limit; at low stresses the strengthening effect predominates over the damaging effect of overstress but is not able to keep up this dominance indefinitely. Ultimately the limit of the ability for local cold working is reached and further repeated stressing produces damage. Hence, the endurance limit for steel can be satisfactorily established by running 5 or 10 million cycles, but in nonferrous alloys not less than 50 million, preferably 200 to 500 million cycles are imposed in careful testing. The endurance stress figures for nonferrous alloys need to be accompanied by a statement as to the number of cycles to which testing was carried, *Figs.* 10 and 11.

Endurance data for most structural materials have been obtained by the rotary bending method. The Fatigue Research Committee of the American Society for Testing Materials has wisely chosen not to "standardize" fatigue testing methods, but instead, to discuss[7] the precautions necessary for reliable and reproducible results.

Fatigue phenomena are independent of speed within the ordinarily practical speeds of testing, so that fatigue tests may be speeded up enough to make them suitable for general use. When corrosion is involved simultaneously with stress, test methods have been worked out to appraise corrosion-fatigue resistance, but corrosion takes time, and such tests cannot be speeded up very much. *Fig.* 12 shows the behavior of steels of different strengths and hardness, tested in fatigue as polished bars, bars with notches, or polished bars with simultaneous corrosion. This brings out two important facts: First, that when notches are present, very strong steels as a class are no better than moderately strong ones and, second, that there may be a high degree of scatter in fatigue results of different steels of the same static strength.

In fatigue testing there is no analogy to the ductility measurements of the tensile test. Fatigue fractures may, and usually do, occur without any measurable permanent distortion of the piece. Such fractures usually occur when no applied stress has ever been as high as the yield strength. In line with this is the fact that the ductility values determined in the tensile test have no correlation with fatigue resistance. The phenomena of stretching and necking down have no opportunity to come into play. The same is true of the notched-bar impact test, whose results throw no light on fatigue problems.

That is, in fatigue, notch sensitivity is measurable only by the ratio between the polished endurance limit and the

[7] Research Committee on Fatigue of Metals—"Summary of Present Day Knowledge of Fatigue Phenomena in Metals", *Proceedings* A.S.T.M., Vol. 30, Part 1, 1930, Pages 260-310.

Fig. 15—Comparison of Charpy values for malleable cast iron at various temperatures, with 70 foot-pound wedge test

Temperature (F)....	*—50*	*—30*	*0*	*75*
Charpy value (ft-lb)	*3.5—4*	*5*	*5.5—6*	*8—8.2*
Blows on wedge....	*14—22*	*22—24*	*27*	*30—30*

notched endurance limit; there is no other criterion. The notched-fatigue limit has to be determined directly.

If we know that the repeatedly applied stresses are at a definite level, the endurance and the notched-endurance limits have a "pounds per square inch" meaning. If stresses above those limits are to be applied, but the engineer cannot state their intensity or number and nevertheless demands evaluation of a material for "guts" to stand undefined overload punishment, the testing engineer is in a quandary.

Overloads and Damage

Most engineering metals will stand quite a number of high overloads without distortion or damage. That is, if the repeated stress is thereafter lowered to that of the endurance limit, the not-too-greatly-abused specimen will last indefinitely, in spite of having been overloaded. The part would fail if the overloads were indefinitely repeated, yet it will not even distort in one such overload below the yield strength. Somewhere between the one, harmless, and the finite number, fatal, of overloads is a dividing line between a nondamaging and a damaging number. No crack develops during the nondamaging period, nor does it develop visibly, if it is there at all, in the first part of the damaging period. A crack does develop toward the end of the damaging period; after the crack starts, failure is certainly inevitable at the stress level of the endurance limit, where material undamaged by repeated overload would not fail.

Reasonable basis for evaluation of the propensity toward or relative freedom from damage might be had through an arbitrary schedule of overstressing. A specimen could be run for some definite fraction of the life it has shown at some definite overstress as a virgin bar, then be run at a lower stress, i.e., at the endurance limit or only at slightly above the endurance limit. The behavior at this lower stress, compared with the behavior of a virgin specimen, will show whether the specimen was or was not damaged. Some such damage data exist, and are collected in "Prevention of the Failure of Metals Under Repeated Stress", a handbook prepared for the Bureau of Aeronautics, Navy Department, but few have been obtained on such a schedule as to be thoroughly comparable with each other.

Far too few data exist on different classes of steel, different structures resulting from heat treatment and different heats of ostensibly similar steels, to allow generalizations about damage. It is, however, certain that steels, structures, and probably heats, do vary in resistance to damage. It is also certain that no way of revealing fatigue damage is known save the very tedious method of overstressing and then running fatigue tests on the overstressed specimens.

The scatter among duplicate tests of virgin bars, resulting in a S-N band, means that many damage tests are necessary in order to establish the trend of behavior. Attention to the elimination of scatter will have to precede accurate knowledge of damage behavior. An important clue to one cause of scatter on polished-bar endurance tests seems to be emerging from current investigations. The importance of the surface cold working that occurs in mechanical polishing has evidently been greatly underestimated. In supposedly "duplicate" specimens, various amounts of final polishing may be required to remove scratches left from earlier operations and these variations in cold work are reflected in variations in life, i.e., scatter is produced. Without some such cause the distribution curve of *Fig.* 13 should have equal deviations from the mean, whereas the deviation is markedly on the side of increased life, presumably representing those specimens that received more cold work.

The data of *Fig.* 13 were obtained as a prelude to damage studies. A specimen from each bar of the low carbon steel used was tested at 45,500 pounds per square inch and unless it broke at close to 30,000 cycles, that bar was discarded. The bars that passed were made into polished fatigue specimens, overstressed as indicated in *Fig.* 14, then S-N curves were determined to give the new endurance limits, after overstressing. The tendency toward increased lowering of the new endurance limits with increasing number of cycles of overstress is clear, but the scatter in individual sets was large. Conclusions drawn from a few specimens in the study of damage on a given heat may not be sound because of uncertainty due to scatter.

Increasing use of recording strain gages in aircraft flight testing suggests that there are now available, or may readily be made available, data showing with a reasonable degree of reliability the relative intensities of the succession of repeated stresses to which any part of an aircraft is expected to be subjected in service, provided that a suitable strain gage may be applied to that part. That is, the frequency of occurrence of low and of high stresses could be plotted in a curve representing both the periods of understressing (and strengthening) and of overstressing (and possible damage).

A laboratory test could then be devised to apply a sequence of repeated stresses correctly representing these periods and could be continuously applied to an actual, full-sized, aircraft part (with all its stress raisers), divorced from the rest of the plane, thus allowing a test to

be carried out in a few weeks that might correspond to the expected years of actual service.

The question would arise as to the effect of the sequence of stresses, for if the total number of peak stresses expected in the life of the plane were crowded closely together without long periods of intermediate understressing, the opportunity for repair would be minimized, but this question likewise might be fairly promptly answered by well-chosen variations in the laboratory test.

Determining Notch Sensitivity

Materials that ordinarily are appraised as tough sometimes fracture in brittle fashion under a single blow. Our first impulse is to blame the material and try to set up a test to evaluate its propensity toward brittle behavior. On the assumption that the test tells all, we are then prone to draw unwarranted conclusions from the test figures.

The test consists in measuring the foot-pounds of energy absorbed in fracturing a bar carrying a notch of such severity that any engineer would do his best to avoid it if he could possibly find a way to do so. Results are reproducible *only* for a given size bar and given notch. Scale models do not tell consistent stories. This should at once make us suspicious of data given by a tiny specimen. The whole thing boils down to the fact that notch brittleness depends as much on the geometry of the piece and the restraint this geometry of size and shape imposes upon plastic deformation, as upon the ability of the material to deform in plastic fashion.

According to theory, brittle behavior depends on the ratio of shear strength to cohesive strength, and on the ratio of applied shear and tensile stresses. Unfortunately, no one knows how to measure cohesive strength; even its order of magnitude has to be judged by indirect methods. A material is ductile in the tension test when the cohesive strength is twice, or more than twice, the shear strength. A notch increases the ratio of tensile to shear stress.

When a material is without ductility in the tension test, and gives a flat break, without necking, the notched-bar test likewise shows it brittle. This is the case with cast iron. The reverse is not necessarily true. When a material does have ductility in the tension test, and thus can deform when conditions of constraint allow it to deform, and it starts to deform, it cold works. The cold work may alter the ratio of shear to cohesive strength and the ratio may also be altered by temperature.

Notches produce triaxial tension stresses, and the adoption of a "standard" notched bar represents a groping toward the end of subjecting materials to controllable triaxial tension. There is no practical method of either measuring or computing the magnitude of triaxial tension induced by a notch in a crystalline material, and there is no general agreement as to what constitutes similarity between notches in small test bars and those in large parts. This lack of agreement originates from observations that notches which are supposed to be "geometrically" similar do not produce the same results on large parts as they do on small test pieces. This means that there is a "scale" effect in the geometry that is not completely understood.

Brittleness or toughness in the notched-bar impact test is not an indicator of notched-fatigue behavior. Cast iron, very brittle in the single-blow notched-bar test, is insensitive to notches in fatigue. A striking case of lack of correlation is reported by Inglis[8] for a certain lot of constructional nickel-chromium steel which, in elevated temperature service at 750 degrees Fahr. for several years, dropped in room temperature notched-impact from 38 foot-pounds to 4 foot-pounds, but endurance tests on threaded specimens of the steel in the two conditions gave exactly the same—23,500 pounds per square inch notched endurance limit.

If we are not going to subject the material to stress conditions conducive to brittle behavior, low notched-bar impact figures are not a detriment. The Ford crankshaft, *Fig.* 8, with around one foot-pound yet serving in millions of cars, is an excellent example.

In World War I, aircraft engine crankshafts were evaluated with great attention to securing high notched-bar

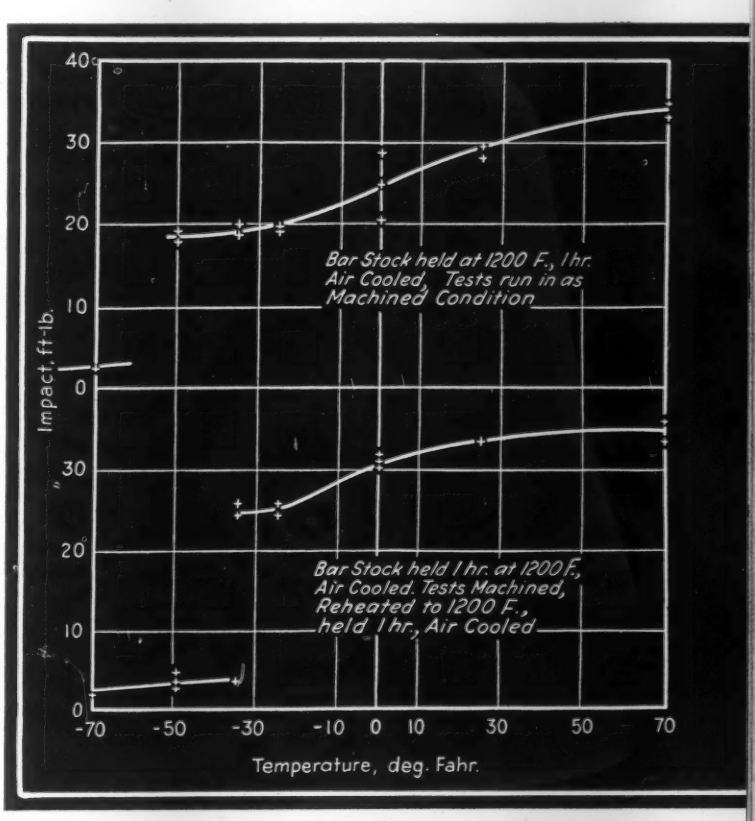


Fig. 16—Charpy data at low temperatures on .35 per cent carbon steel. Scatter at —35 degrees shows borderline condition

values. At present, nitrided crankshafts for the Rolls Royce aircraft engine are specified at 55 foot-pounds Izod minimum in the core. In an early type of the German Jumo 211 engine for some of the Junkers planes, specimens of crankshafts from captured engines showed some 70 foot-pounds impact, but in a later type the crankshaft (though not of a regular nitriding steel) was nitrided for better wear resistance and the impact figure was reduced to some 10 foot-pounds.[9]

(*Continued on Page* 206)

[8] Inglis, N. P.—"Relationship Between Mechanical Tests of Materials and Their Suitability for Specific Working Conditions". *Transactions* N. E. Coast Ind. Engineers and Shipbuilders, Page 53, Pages 101-136, 1936-37.

[9] Aero Components Subcommittee—"A Metallurgical Study of German and Italian Aircraft Engine and Airframe Parts", *Metallurgia*, Vol. 26, Aug. 1942, Pages 129-136.

Designing Bearings for Film Lubrication

By Arthur H. Korn
Chief Engineer
Holly Pneumatic Systems Inc.

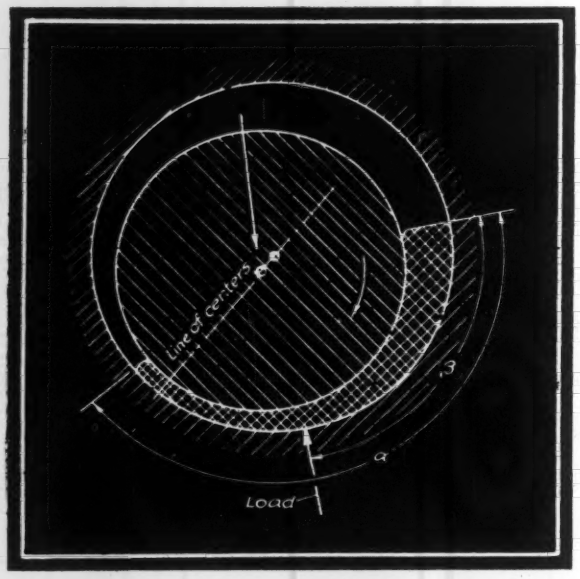


Fig. 1—Discrepancies in test data for bearings occur because of differences in angle covered by supporting film

***ALTHOUGH** load-carrying characteristics of sleeve bearings have been the subject of considerable research and investigation, seeming discrepancies appear in the results from different sources. To provide the designer with working data on such bearings, this article reviews available information and combines test results from two authoritative sources in the form of a practical chart*

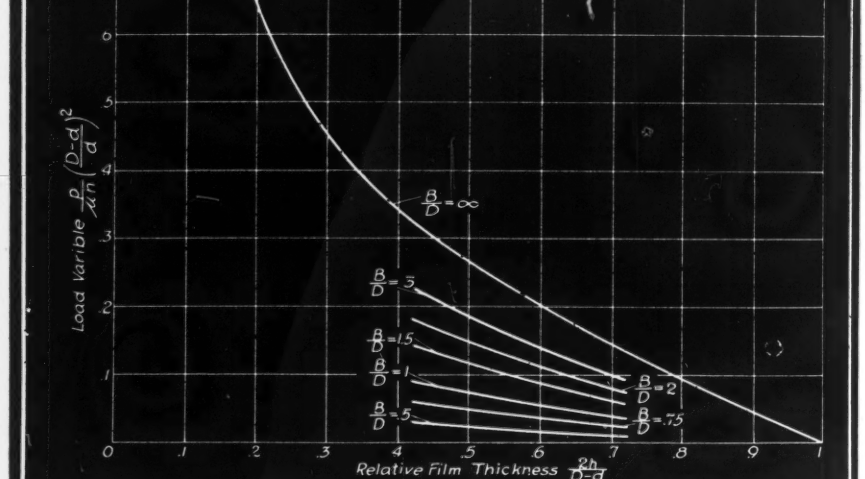


Fig. 2—Sleeve bearing load characteristics include Kingsbury correction factors for side leakage under optimum film proportions

SLEEVE bearing characteristics determined from several sources are reproduced in the accompanying diagrams in such a manner as to admit direct comparison. The variable $(p/\mu n)[(D-d)/d]^2$ which represents the load-carrying capacity of a bearing is shown as a function of the relative oil film thickness $2h/(D-d)$. Film thickness is more important to machine designers than the more generally used relative eccentricity, $1—2h/(D-d)$.

It is comparatively simple to derive mathematically the load variable for a full bearing without side leakage or one of infinite width. Yet the curves for such a bearing given in hand books and textbooks differ considerably due to the fact that the effective film arc α, *Fig.* 1, is by no means 360 degrees. The exact actual angle covered by the supporting film is not known. The load variable given in Kent (1)* and shown in *Fig.* 2, is based on an effective film arc of 180 degrees, while according to Marks (2) the angle β between entering edge of film and load line is assumed to be 60 degrees which would correspond to an effective film arc of approximately 110 degrees for optimum conditions. Loadings for bearings without side leakage given in Reference (2) are therefore lower by as much as 33 per cent for a relative film thickness of .2, up to 56 per cent for a thickness of .8.

*Numbered references are listed at end of article.

TABLE I

Load Variable Disagreement

Deviation of *Fig.* 4 from *Fig.* 2, per cent

B/D	Values of 2h/(D-d)					
	.45	.50	.55	.60	.65	.70
3	+8	+3	0	0	+2	+7
2	+9	+4	+1	+2	+3	+8
1.5	+9	+5	+2	+2	+4	+9
1.0	+7	+3	0	0	+2	+7
.75	+7	+2	0	0	+2	+6
.50	+6	+2	—1	—1	+1	+6

To find the load variable of a bearing of finite width the curve values for a bearing of infinite width have to be multiplied by a correction factor. A curve of correction

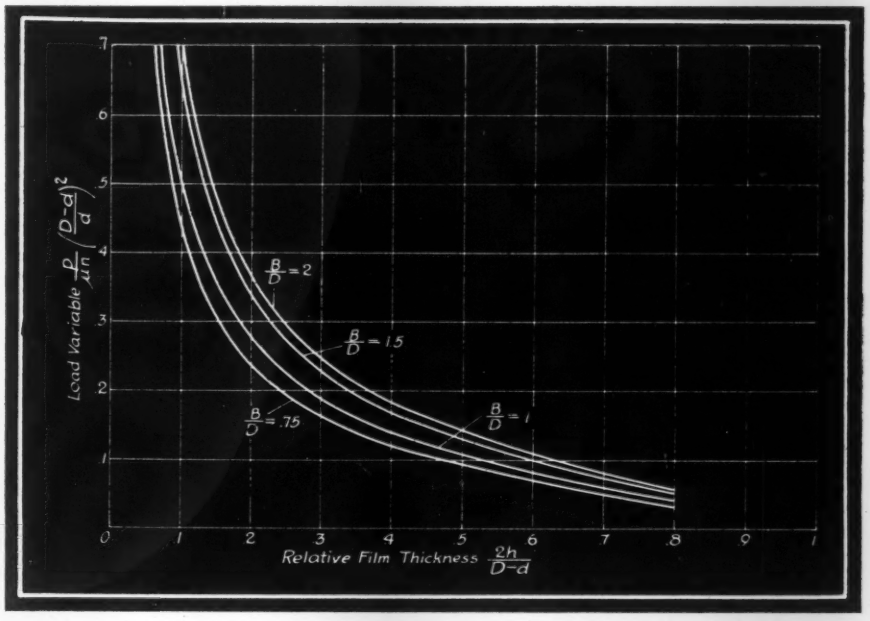


Fig. 3—Right—Load variables for sleeve bearings as reported by Sachs

factors for optimum film proportions given in Kent has been established experimentally by an ingenious method based on the Kingsbury electrical analogy, and checks closely with the few calculated points available. Difficulties arise again in applying these factors to full bearings on account of the more or less arbitrarily assumed effective film arc. Correction factors given in Marks agree with the Kingsbury factors for a film arc α of approximately 110 degrees. In the absence of more accurate data they are apparently to be applied for the entire range of relative film thicknesses, though strictly valid only for optimum thicknesses.

The load variable given in *Product Engineering* (3) and shown in *Fig.* 3, has basically the same form as all others. This load variable can be obtained approximately by multiplying the values from curve $B/D=\infty$, *Fig.* 2, by the following correction factors:

B/D =	2	1.5	1.0	.75
Correction factor =	.55	.50	.41	.35

The origin of these correction factors, which cannot be reconciled with the Kingsbury correction factors, has not been disclosed so that it is difficult to say whether they approach actual conditions more closely than the Kingsbury factors, which have a theoretical basis.

The load variable given in MACHINE DESIGN (4) is expressed in a simple formula:

$$\frac{p}{\mu n}\left(\frac{D-d}{d}\right)^2=\frac{.0702}{c}\left(\frac{D-d}{2h}\right)^{1.7} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where

$$c=1+2\left(\frac{D}{B}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

This equation closely represents extensive test results for the bearing ratio $B/D=15/11$ and a relative film thickness of between .2 and .8. With this known it is no longer necessary to hazard a guess as to the effective film arc. The question is now simply: What effective film arc will reconcile these test results with the Kingsbury correction factor? *Fig.* 2 shows the load variable for $B/D=\infty$ given in Kent multiplied by Kingsbury correction factors for an effective film arc of $\alpha=170$ degrees. *Fig.* 4 represents the formula given in MACHINE DESIGN. The percentage of disagreement with values of curves in *Fig.* 2 is given in TABLE I. It can be

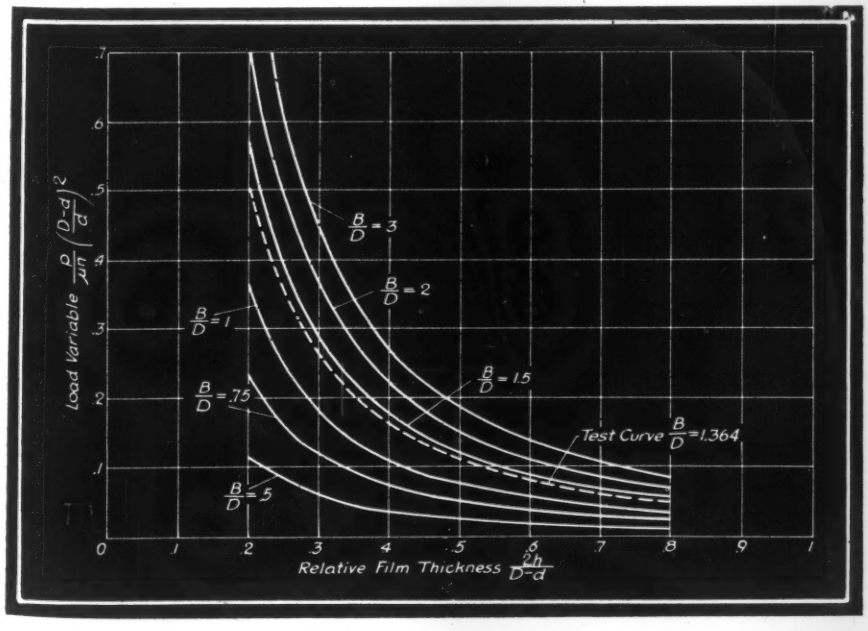


Fig. 4—Left—Characteristics of sleeve bearings, based on tests by Rumpf. Curve for the test bearing is shown by a broken line

seen that the agreement is nearly perfect for relative film thickness between .5 and .65. These are the usual optimum film thicknesses and for these only are Kingsbury corrector factors valid; further, for these only can they serve as a criterion. It also should be borne in mind that it is hardly possible to read the graphs given in handbooks with an error of less than ± 2 per cent.

The first three cases discussed use, as underlying equation, that for a bearing of infinite width, derived by mathematical analysis, while the fourth one starts out with an experimentally established equation for a bearing of common proportions. In all four cases the load variable for a bearing of other proportions than the one of the basic equation is arrived at by the use of a correction factor which is a function of the bearing ratio B/D. Use of the term "correction factor" in the subject literature is unfortunate since it implies the existence of error. It is more logically referred to as a correlation factor.

There has never been much illusion regarding the validity of this simple expedient. As far back as 1934 there were published correlation factors of wider scope based on tests and presented as a function of the ratio B/D and the film arc α as well as of the relative film thickness (5). Although representing some of the most advanced work on thick film lubrication, the results for some inexplicable reason have been presented only recently (6) in a form which a machine designer could readily use.

TABLE II

Load Variable Disagreement

Deviation of *Fig.* 4 from *Fig.* 5, per cent

B/D	Values of 2h/(D-d)						
	.2	.3	.4	.5	.6	.7	.8
3	+24	+15	+ 6	+2	−2	−3	−1
2	+15	+10	+ 4	+2	+1	−1	−1
1.5	+ 7	+ 3	+ 1	0	0	0	0
1	−18	− 8	− 4	−3	−1	+1	+2
.75	−23	−13	− 8	−4	−1	+2	+4
.5	−31	−21	−13	−6	−1	−1	−1

The ratio of load variables of two bearings of different proportions B/D and different film arc α but for the same relative film thickness is fixed through the correction factors by S. J. Needs. For this reason it is possible to use Equation 1 for the bearing ratio $B/D=15/11$, which represents a test curve, and construct from it the curves of other bearing ratios as shown in *Fig.* 5. A film arc of $\alpha=180$ degrees has been used for this purpose for no other reason than that the theoretical curve $B/D=\infty$ of *Fig.* 2, and the test curve $B/D=15/11$ of *Fig.* 4, can best be reconciled with Needs' correction factors. The curves in *Fig.* 5 are thus entirely constructed from test data. Of interest is the percentage of disagreement of Equation 1 from these curves, TABLE II. The deviation is solely caused by the correction factor $c=1+2(B/D)^2$. Since the test data at present available are meager and in view of the fact that none of the methods by which load characteristics of sleeve bearings have been obtained are beyond criticism, the comparison of the curves seems to be favorable for common ratios and film thicknesses.

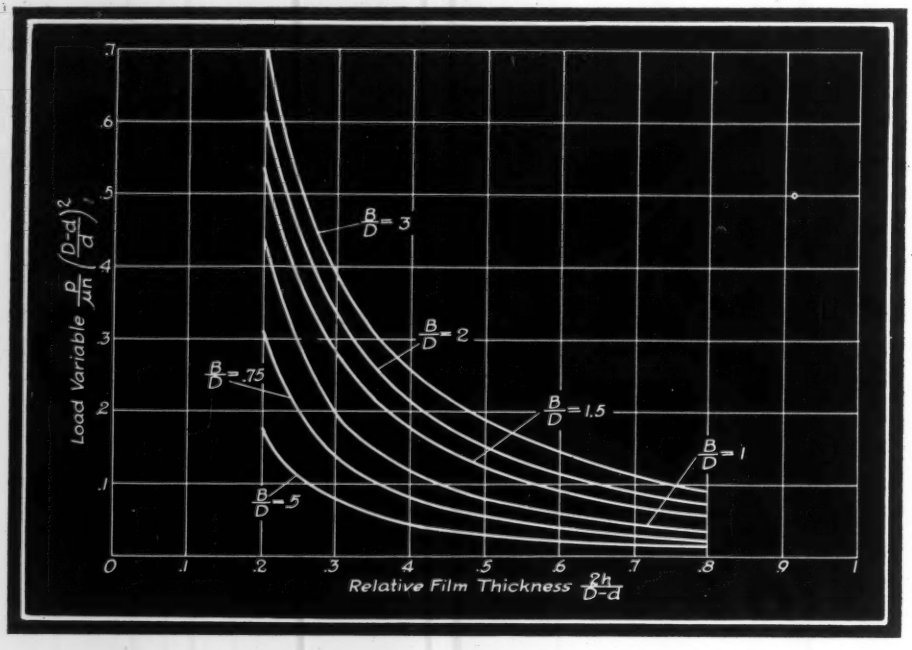


Fig. 5—Sleeve bearing load characteristics, based on the test curve in Fig. 4 and on correlation factors determined by Needs

Nomenclature

D = Diameter* of bearing, inches
d = Diameter* of shaft, inches
B = Axial width of bearing, inches
p = Unit pressure on projected bearing area, psi
μ = Absolute viscosity of lubricant in Reyns, pound-seconds per square inch
n = Velocity in revolutions per minute
h = Minimum oil film thickness
α = Angle of effective film arc, degrees
β = Angle between entering edge and load line, degrees

*The bearing clearance *D-d* appearing in the equations of the hydrodynamic theory of lubrication applies only to absolutely smooth and perfectly cylindrical journals and bearings. In practice the clearance is to be considered greater than *D-d* by the amount of the surface roughnesses.

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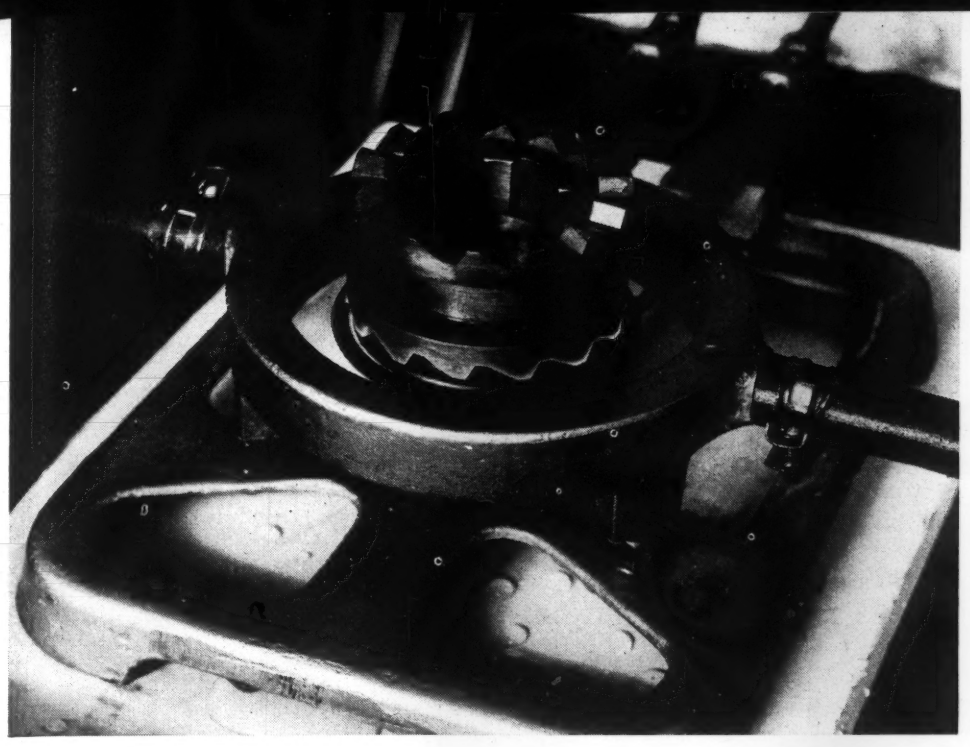

Fig. 1—Typical heating and quenching unit, showing toothed portion of a clutch member being hardened

Developing an Induction Heating Machine

By William Tuerck, Jr.

Chief Engineer—Electronics Division
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WITH the efficient and economical performance of production operations such as hardening, brazing, soldering, tempering, etc., dependent on equipment which will supply quick, accurately controlled heat, induction-type heaters are earning ever-increasing recognition. One of the leading types of induction heaters is the spark-gap high-frequency induction oscillator, depending, as the name implies, on the action of spark-gaps for its operation. Before discussing the design details of such a machine, the operating procedure might be summed up as follows:

Low line voltage is stepped up to

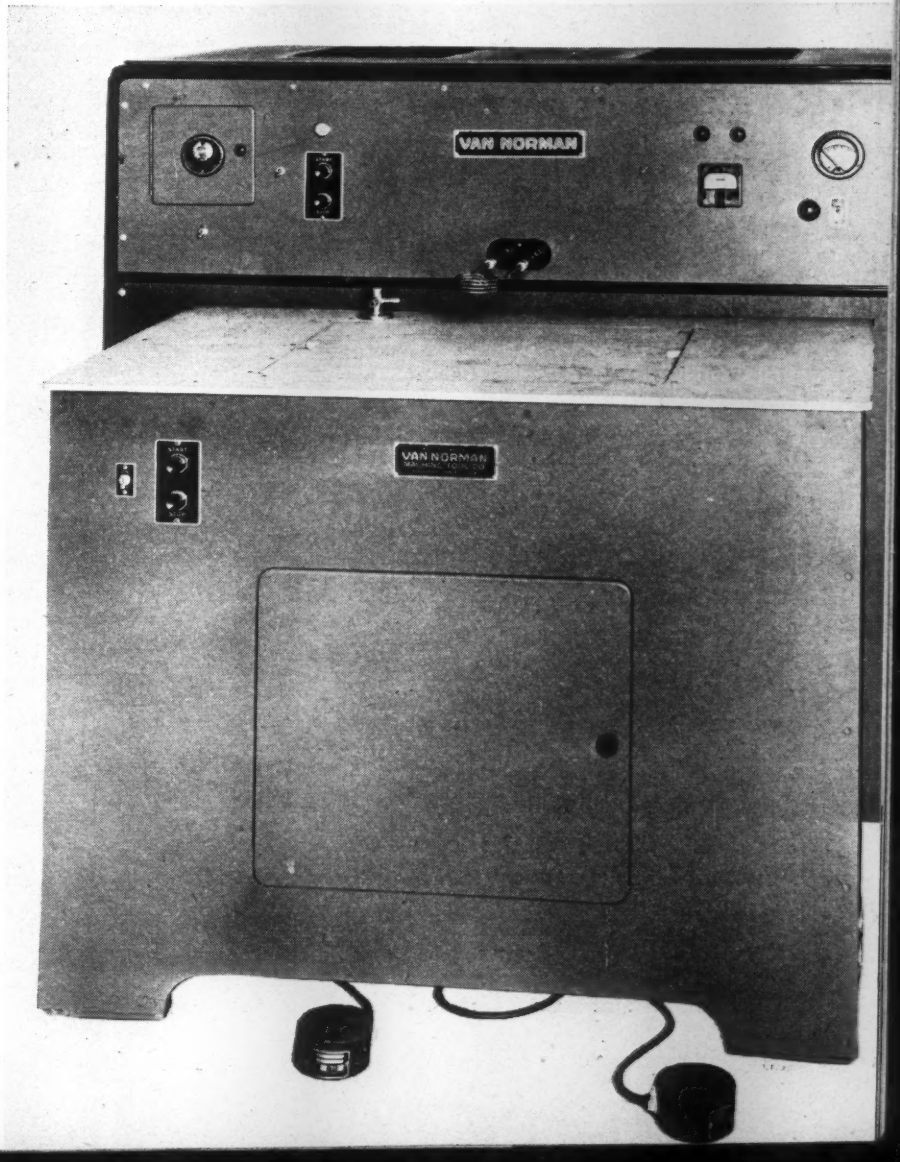
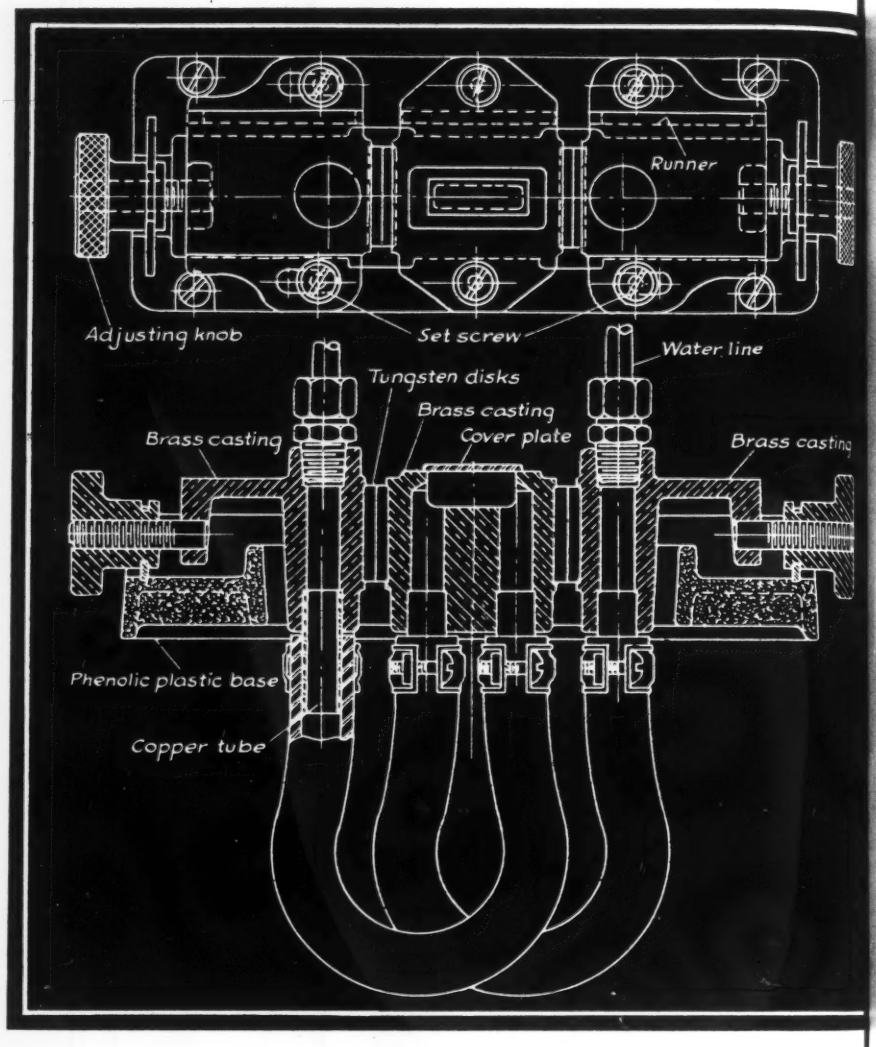


Fig. 2—General view of complete machine consisting of oscillator unit, shown at rear, and utility cabinet which contains the heat-quench assembly

Fig. 3—Assembly drawing of a water-cooled gap unit. Tubes carry cooling water to disk members



about 20,000 volts by means of a transformer, impressed across a set of spark-gaps, which, in turn, are shunted by means of a series-parallel tuned circuit. This tuned circuit, in conjunction with the spark-gaps, provides the necessary high-frequency currents needed for induction heating.

For induction-heating equipment to perform efficiently, the heating and quenching operations must be effected quickly and in a manner permitting the operator to handle the parts with utmost dispatch. A typical heating and quenching unit is illustrated in *Fig.* 1, where the toothed portion of a clutch member is shown in the process of being hardened. Essentially the unit comprises a heating coil (visible beneath the clutch member) and a quenching ring. Parts to be treated are placed on the coil, heated to the prescribed temperature and quickly quenched by a water spray emanating from holes in the inner diameter of the quenching ring.

Two Types of Gaps Employed

Fig. 2 shows the general appearance of the complete machine, consisting of the oscillator and a utility cabinet containing the unit pictured in *Fig.* 1. Inside arrangement of the various component parts of the oscillator unit is pictured in *Fig.* 4, with the spark-gap assemblies shown on the right. These spark-gap assemblies constitute the operational "heart" of the oscillator and include two types—water-cooled and air-cooled. The water-cooled gaps are the principal units, while the air-cooled gaps are used as auxiliaries.

Fig. 3 shows an assembly drawing of a water-cooled gap unit. It consists of three brass castings mounted on a phenolic plastic base, on which the castings are free to slide over runners. To these castings are brazed the tungsten disks, two on the center section and one on each side casting. These tungsten discs provide the sparking surfaces and are machined perfectly parallel to one another to insure uniform arcing. Since the arcing on these surfaces will create heating, means for cooling have been

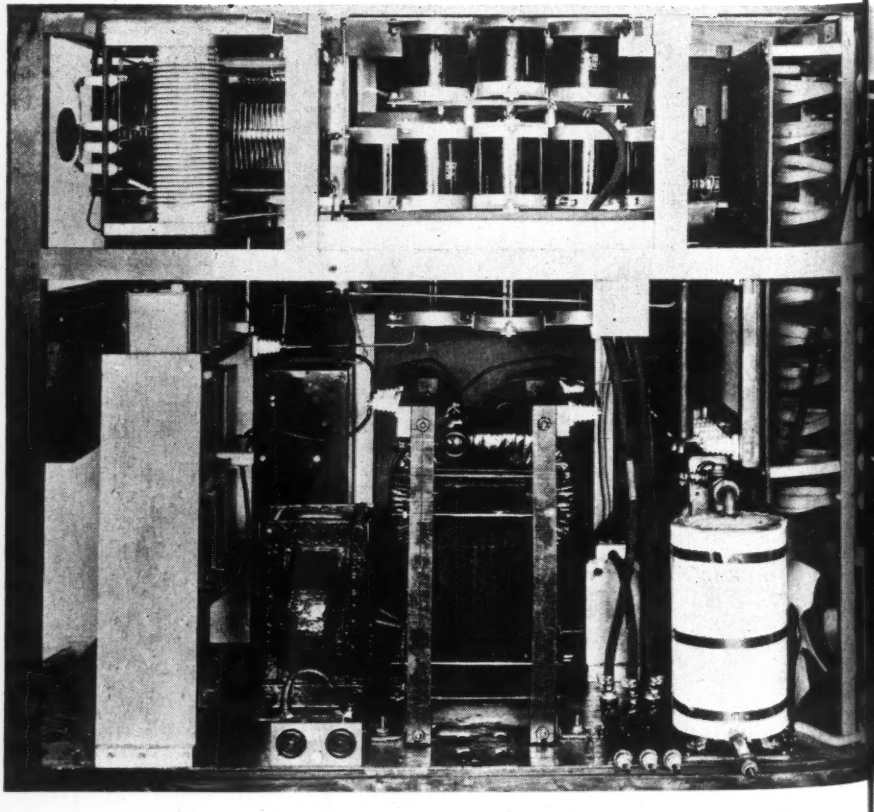


Fig. 4—Arrangement of component parts of oscillator unit with spark-gap assemblies at extreme right

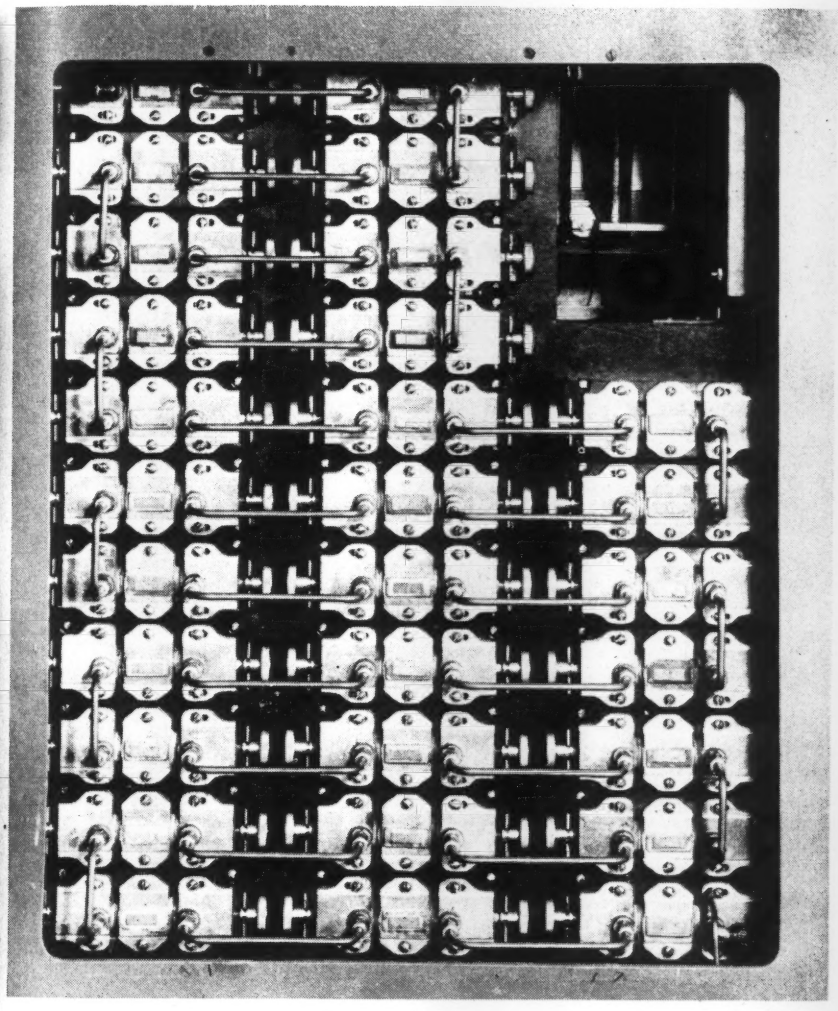
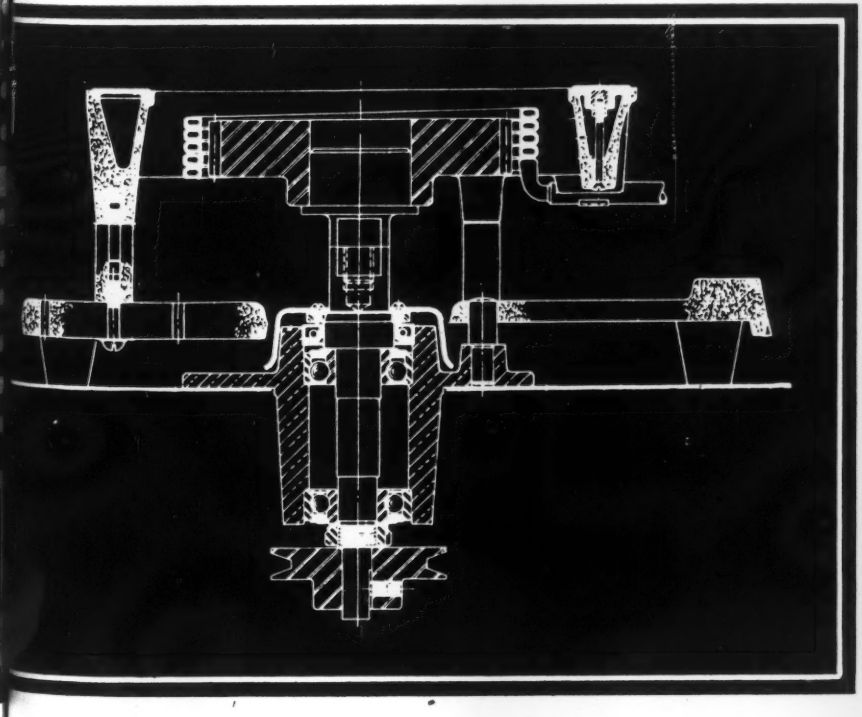


Fig. 5—Above—View of side of machine with cover removed, showing gang of spark-gap units mounted on panel

Fig. 6—Below—Rotating fixture for hardening gears. Quenching ring is outside the heating coil which immediately circles the gear



carefully designed and incorporated as shown in the bottom view of *Fig.* 3. Water enters through the copper tube, flows through the right-hand casting and rubber hose loop to the center section, then back to another rubber loop to the left casting, and out to another similar assembly. Purpose of the rubber hose loops is to eliminate a direct electrical connection between the three castings of the unit.

Because of the large impact produced by sparking on the tungsten disks, these disks are made from forged tungsten and later stamped out by dies.

Brazing of Disks Important

Particular attention has been given to the importance of thorough and accurate brazing of the tungsten disks to the gap castings. Selection of proper brazing material plus thorough cleaning of surfaces has resulted in a satisfactory solid braze. Too hard for machining, being about 45-C rockwell, the disks are ground on their surfaces and diameters, so they are parallel to one another and also concentric. Rubber hose connections are made to the castings by means of a copper tube (see *Fig.* 3) soft-soldered into the casting.

Again referring to *Fig.* 3, the center casting has a brass plate soft-soldered on the top to close the opening. This simplifies machining of the part, as well as the casting, since all holes are drilled and milled. The base consists of a phenolic plastic molding, provided with brass inserts. Material specifications require this plastic base to be heat resistant, arc resistant, a good insulator, and resistant to water absorption. A phenolic plastic with an asbestos base was selected as most closely approaching the desired specifications.

By means of a feeler gage, the sparking gap between the two adjacent tungsten disks is adjusted to 0.003-inch. This adjustment is accomplished by loosening the setscrews on the two side castings and turning the adjusting knob until the gage just passes between the disks. Then the setscrews again are tightened to insure permanence of the adjustment. Depending on the size of the machine, a number of these gap units are placed on a die-stock panel and connected in series as shown in *Fig.* 5.

In series with this set of water-cooled gaps is a set of air-cooled gaps. These are needed because of the electrical

(*Concluded on Page* 194)

Designing Electronic Control Devices

By W. D. Cockrell
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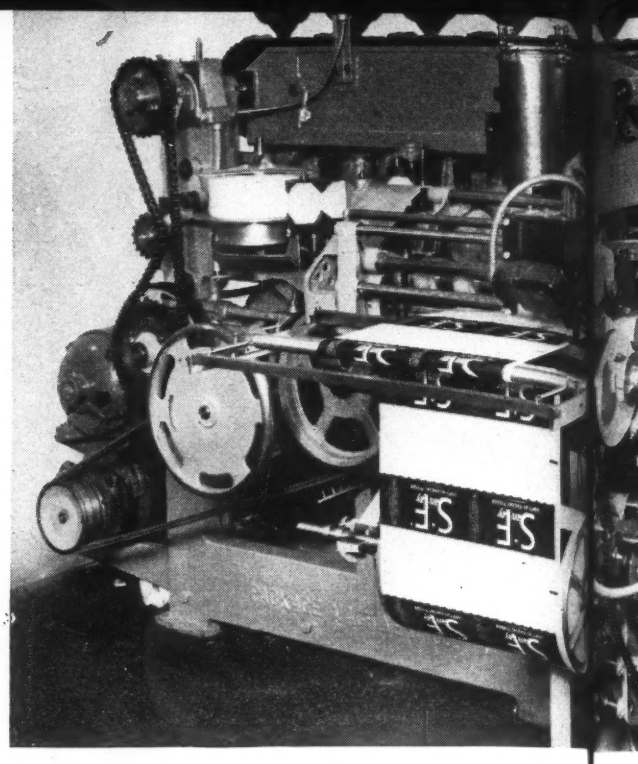
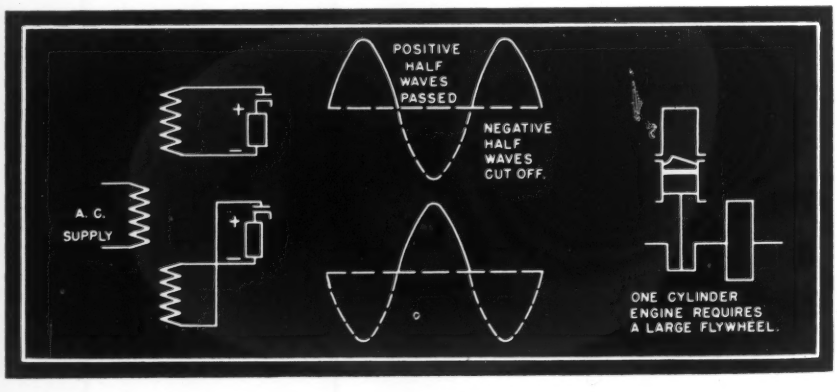


Fig. 1—Above—Photoelectric register control for label positioning on wrapping machine

Fig. 2—Below—Half-wave rectifiers compared with one-cylinder gasoline engine. Curves show power output against time



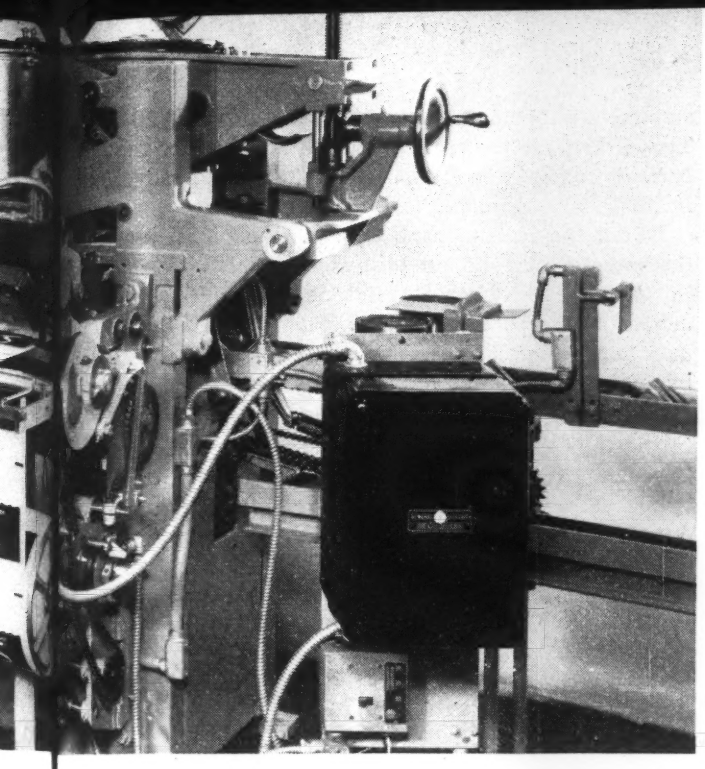
MECHANICAL engineers have a larger stake in electronic control, particularly in photoelectric control, than many realize. In this new tool they have a means of supplementing mechanical operations in many ways. Electronic tubes, almost infinitely fast and inertialess, can supplement mechanical control to produce many results hitherto considered impossible. A beam of light, a small voltage, or a change in magnetic or electrostatic field, produced by mechanical or chemical means, may act as a lever, pushrod, cam follower, or trip latch. A typical application is the register control illustrated in *Fig.* 1.

The electron tube may be described as a valve. With only one of the elements capable of emitting electrons, current can flow in but one direction, making a one-way valve. Some applications use the one-way effect, others employ throttling effect, while a few utilize both.

RECTIFIERS: The one-way action may be used like a mechanical pawl-and-ratchet motion or, if preferable, like a crank-and-piston to transform the alternating current normally supplied by the power companies into direct current which is more useful for operating variable-speed motors, for charging batteries and for many chemical processes. Alternating voltage usually supplied to a transformer reverses its potential 120 times per second. If a two-element electron tube is connected in such a circuit, it will permit the electrons to flow only when the anode potential is positive. Therefore the current will flow through the load in only one direction, but, since the power supply is reversed half the time, this load current will be intermittent. This is similar in action to a one-cylinder gasoline engine and, like the gasoline engine, a large electrical flywheel is necessary to provide continuous power to the load, *Fig.* 2. To secure a more even flow of power, a reverse transformer winding may be used to supply a positive potential to a second rectifier the half-cycle that the first is inoperative, *Fig.* 3. This, of course, provides better direct-current output with a smaller electrical flywheel. Finally, by using a number of tubes, 3, 6, or 12, and a multiphase alternating-current supply, smooth direct-current power may be produced, just as a multicylinder gasoline engine produces a smooth flow of power with a minimum sized flywheel. An analogy between this type of electrical power and the uniform output of an engine is shown in *Fig.* 4.

THE ELECTRONIC AMPLIFIER: Another important use of electronic tubes is to amplify, or step up, a weak input signal to a strong output signal. This input signal must be applied to the grid of the amplifier tube as a voltage or potential change. If the weak signal is in the form of a small current, it must be transformed to a voltage by forcing the current through a high resistance to obtain a large potential difference across it. It is similar to

Abstract of a paper presented at the recent New York annual meeting of The American Society of Mechanical Engineers.



obtaining a high-pressure reading from a small flow of water by forcing the water through a small pipe. This resistance may be many million ohms so that, should the input signal consist of currents expressed in millionths of an ampere, the voltage produced will be usable. No power is required on the grid of the tube, but some power is required in this input resistor.

Change in potential on the tube grid will cause a change in the current or electron flow between cathode and anode. If another resistor, or impedance, through which the tube current must be forced, is placed in series with the anode the potential change in this impedance will be much greater than that of the grid-potential change. If this in turn is transferred to the grid of a second tube and its anode current is again passed through an impedance to control the grid of a third tube, it is evident that immense amplification or magnification of the first potential change will be available at the anode of this final tube, *Fig.* 5. Most amplifier circuits transfer their signal between an anode and following grid through a capacitor or transformer, but the principle remains the same.

It should be noted that no power has been produced by the tubes. They have simply acted as valves to release a larger amount of power from some external power source, such as a battery which forces current through the tubes and their connected impedance. Theoretically, signals can be amplified thousands of times in a single tube and, in standard industrial applications, a voltage amplification of hundreds of times and power amplification between input and output of millions of times is common.

OSCILLATORS: Since the power required at the grid of the tube is only a small part of the output-controlled power, a small amount of this output power may be fed back to control the grid at the proper frequency, thus obtaining a controlled alternating-current output from the direct current supplied to the tube, *Fig.* 6.

Rotating equipment can generate frequencies up to 5000 or 10,000 cycles per second. Because of the immense speed of the electrons, electronic equipment can generate frequencies up to many millions of cycles per second.

Oscillator tubes provide the type of power necessary for radio broadcasting, dielectric heating of plastics and induction heating of small pieces of metal. It must be remembered however, that control of any large amount of power by the use of high-vacuum tubes is extremely expensive. For this reason, most electronic control of industrial power is ultimately obtained from the gas-filled tube.

Gas-Filled Tubes

When in a simple two-element vacuum tube, the electrons are being drawn from cathode to anode, an interesting thing happens. Electrons move across the space because they are negative charges attracted by the positive anode. Since they themselves are negative, however, they will tend to shield all electrons between themselves and the cathode from the action of the anode in the same manner that the negative grid does. This effect is so great that, in order to obtain the one ampere of current necessary to light a 100-watt lamp, it might be necessary to apply 1000-volts between anode and cathode. This means that high-vacuum tubes are most useful at low currents or with high-voltage loads.

However, if a small amount of gas is introduced into a vacuum-tube envelope, about .0001 of atmospheric pressure, a remarkable change in this space charge takes place. The gas may be inert, such as argon or xenon, or the mercury vapor above a small drop of mercury at normal room temperature.

If the positive potential on the anode is not more than

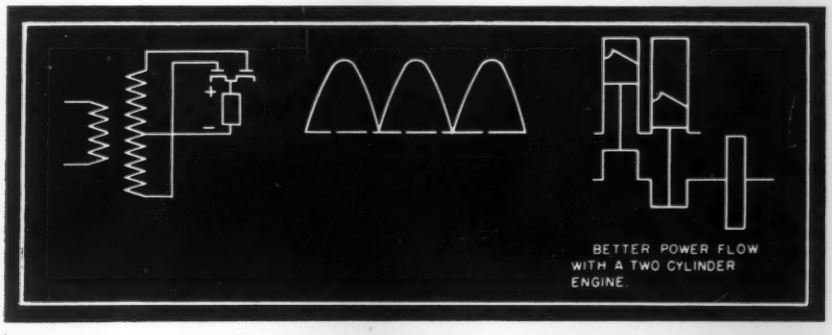
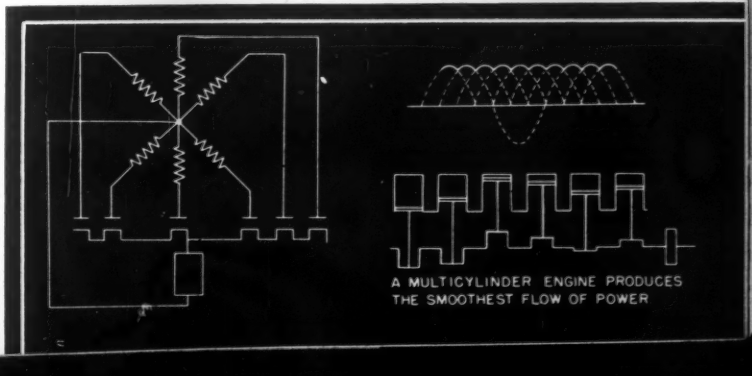


Fig. 3—Above—Full-wave or biphase half-wave rectifier with 2-cylinder engine analogy

Fig. 4—Below—Multiphase rectifier produces smooth direct-current output



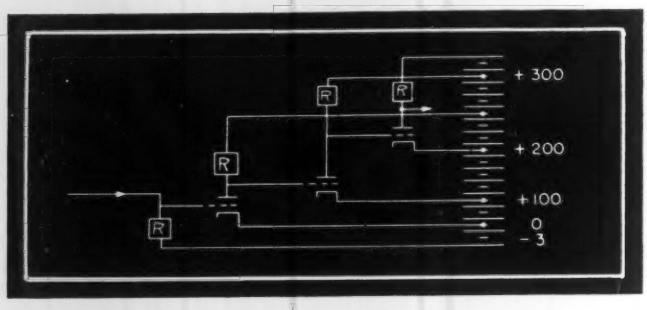


Fig. 5 — Above — Three-stage vacuum-tube amplifier circuit

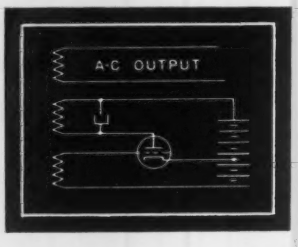


Fig. 6—Left—Vacuum-tube oscillator to convert direct-current power to alternating current

eight volts, then the electrons leaving the cathode bump into the many gas molecules in their path to the anode so that their progress is slowed down considerably and the current flowing is small. However, somewhere between 8 and 12 volts, depending on the type of gas and the pressure, some electrons attain sufficient speed so that, in striking these gas atoms, they knock an electron or two from them. Then, for each original electron, two free electrons move toward the anode. The atom, losing an electron, becomes a positive ion which drifts toward the cathode. The glancing electron may hit other atoms and knock out other electrons on its erratic course to the anode, until finally almost the whole area between cathode and anode, no matter what its shape or length, is filled with flying electrons and positive ions. Of course, many atoms recombine with electrons giving up their energy in the form of the familiar glow seen in gas-filled tubes. Yet, on the whole, this so-called "plasma" is composed of approximately equal numbers of positive ions and negative electrons.

Plasma Potential Is Constant

Electrons are always arriving at this plasma from the cathode and are leaving at the anodes, but the plasma always maintains a potential of about 10 or 15 volts positive with respect to the cathode. If more electrons should leave than arrive, the average potential of the plasma will rise, accelerating the electrons to a higher speed, thus knocking more electrons from the neutral atoms within the plasma. If more electrons arrive than leave, the potential of the plasma will be lowered and the average potential of the arriving electrons from the cathode will be less. Thus, no matter what the current from the cathode, even though it be thousands of amperes, the potential of the plasma will be subjected to very little change.

Mercury-Pool Rectifier and the Ignitron: In the mercury-pool or tank rectifier and in the ignitron, the cathode consists of a pool of mercury. Once ionization has taken place, the positive ion—drifting near the cathode—draws out the electron by the potential-gradient effect. In this manner, a plentiful supply of electrons is assured at a potential drop between 15 and 20 volts. These, then, are the rectifiers which are used for the high currents required for resistance welding, railroad electrification and electrochemical processes.

Before the ionization action can take place, however, the plasma must be established. In the tank rectifier, this is done mechanically and, in the ignitron, by the action of a small crystal dipping into the mercury. For most precise applications this crystal igniter is controlled by a hot-cathode thyratron.

Gas-Filled Tubes With Grids: Since the gas filling in the tube makes possible its use with low losses when conducting high currents, it is the one used for the usual applications requiring power such as driving motors or operating a solenoid. Unfortunately, however, these gas-filled tubes cannot be controlled by a grid in the same manner as are high-vacuum tubes. So a slightly different method of control must be obtained from the grids in the gas-filled tubes.

Hot-Cathode Thyratron: It is evident that the conventional grid, inserted in the gas-filled tube in the plasma between cathode and anode, would have little effect on the erratic and random motion of the electrons and ions

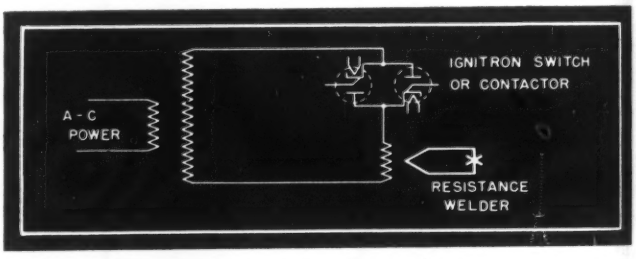


Fig. 7—Above—Inverse-parallel ignitron connection, acting as alternating-current switch to control load such as resistance welder

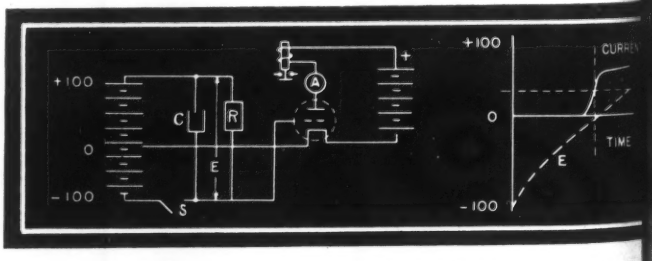
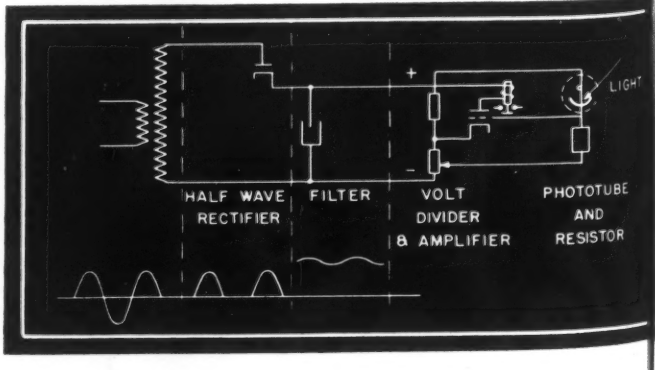


Fig. 8—Above—Elementary electronic timer circuit

Fig. 9—Below—Photoelectric relay circuit combining half-wave rectifier and capacitor filter



filling the space. When the grid is made negative before a positive potential is applied to the anode, it may prevent the flow of electrons as well as the formation of the plasma. But once the plasma has formed, the grid is powerless to stop the electron flow.

Since the grids can only prevent the conduction through the thyratron but cannot stop it once it has begun, a question may arise as to the usefulness of this type of tube. The answer lies in its use on alternating-current power. It will be remembered from the discussion on rectifiers that, when alternating-current power is applied to the tubes, the anodes become positive half the time and negative the other half. During the interval that the anode is negative, no electrons flow and the positive ions may recombine with the electrons or deionize, thus permitting the grid to regain control.

If the grid is negative when the next half-cycle begins,

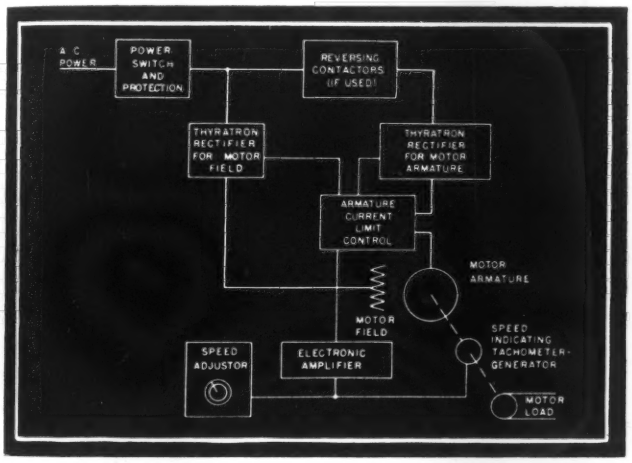


Fig. 10—Above—Example of an electronic motor control system

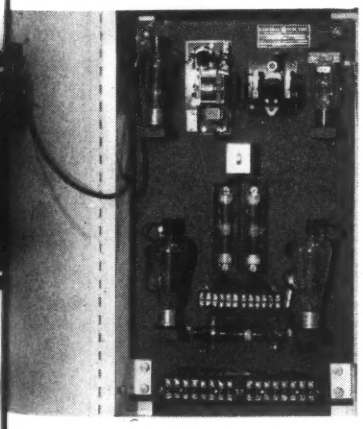


Fig. 11 — Left — Electronic timer controls duration of heat pulse for resistance welder

the electron flow cannot begin until the grid becomes positive. Thus it can determine the point in the positive half-cycle where conduction starts. By retarding the grid-firing angle to the desired point within this positive half-cycle, the average current passed by the thyratron may be controlled and, thus, the output to the load. Identical reasoning may be used concerning the action of the igniter in the ignitron, to decrease the maximum current which may be passed by that tube.

THYRATRON AND IGNITRON CIRCUIT: Thyratrons and ignitrons may be used in the rectifier circuits discussed

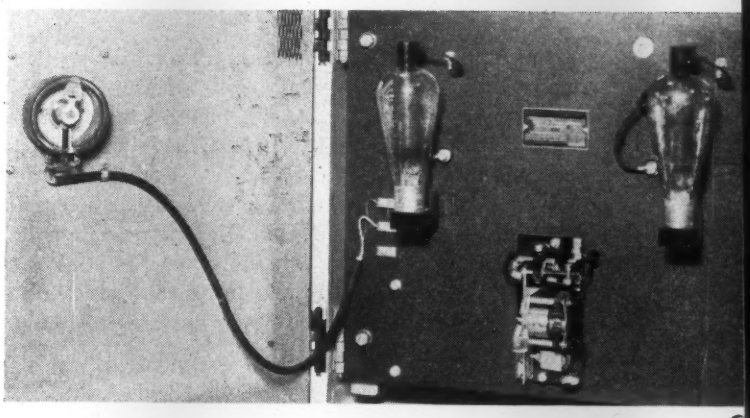


Fig. 12—Above—Thyratron grid-phase control panel to control rate of heating during heat cycle of resistance welder

previously, but with much higher efficiency for larger loads. In fact, multiphase ignitron rectifiers have become the basic means of obtaining direct current from alternating current in many industries. Thyratrons, so connected, supply variable power for control of direct-current motors and similar uses.

Although electronic tubes are inherently rectifiers, two may be connected in an "inverse-parallel" circuit to permit passing both halves of the alternating-current wave. Thus they become an effective alternating-current switch which combines both high-speed switching action and throttling action. It is this type of circuit that is used to supply the precisely measured power for resistance welding, *Fig.* 7.

MISCELLANEOUS CONTROL CIRCUITS: Both thyratrons and vacuum tubes may be used in connection with the more conventional electrical components, such as capacitors and inductances, to produce a variety of functions.

If the energy is stored in a capacitor and then permitted to be dissipated through a resistor, the capacitor potential will be reduced at a well-known and easily calculable rate. If this potential is applied to the grid of an electron tube, the anode current will be varied or the thyratron grid will reach the firing potential in a definite time. In this way an accurate and unvarying timing relay is developed, *Fig.* 8.

Standard Electronic-Control Circuits

By combining the tubes and control circuits discussed many practical applications may be developed. Some of these are discussed in the following:

A PHOTOELECTRIC RELAY: To make a simple photoelectric relay, a rectifier is utilized to obtain direct current from alternating current. At the output end of the rectifier, a capacitor stores energy between the positive pulses of the alternating-current. Across this output is placed a series of resistors which act as a voltage divider to permit obtaining both anode and grid potential from the one direct-current source.

Next, the necessary phototube is added to convert the change in light impulse into a change in electric current. Voltage drop across the phototube resistor is then applied to the grid of an amplifier tube in order to step up the signal sufficiently to operate a small contactor placed in

the amplifier-anode circuit.

As a finishing touch, a rheostat may be added so that the amount of direct current normally applied to the grid may be varied to select the amount of light which must fall on the phototube before the grid is made sufficiently less negative to operate the contactor. For further refinements, a small capacitor may be utilized between grid and plate of the amplifier tube to prevent operation on slight light flickers and another capacitor between the direct-current potential and ground to prevent action due to slight changes in the alternating-current power supply. This circuit is shown in *Fig.* 9.

AN ELECTRONIC TIMER: In a similar manner, an electronic timer may be built by combining the capacitor-resistor fundamental timing circuit with an amplifier and a contactor operated by the amplifier.

TUBE CONTROL OF MOTORS: A motor control, *Fig.* 10, which will regulate the speed of the motor quite accurately can be made by a pair of rectifiers, one or both of which may be controllable, to supply the motor armature and field of a direct-current motor. Then an indication of the motor speed may be obtained either by utilizing a tachometer-generator to produce a voltage proportional to speed or taking the back-induced voltage from the motor. This is compared to a reference voltage, and the difference is amplified and applied to the control of the armature or field to hold the motor speed constant. If desired, other circuits may be added which operate from the motor current to limit this current to a safe value for motor and tube in spite of the demand for speed. To compensate for the resistance of the motor armature a control can be added, obtaining a flat compounding which is superior to that from a direct-current compound motor.

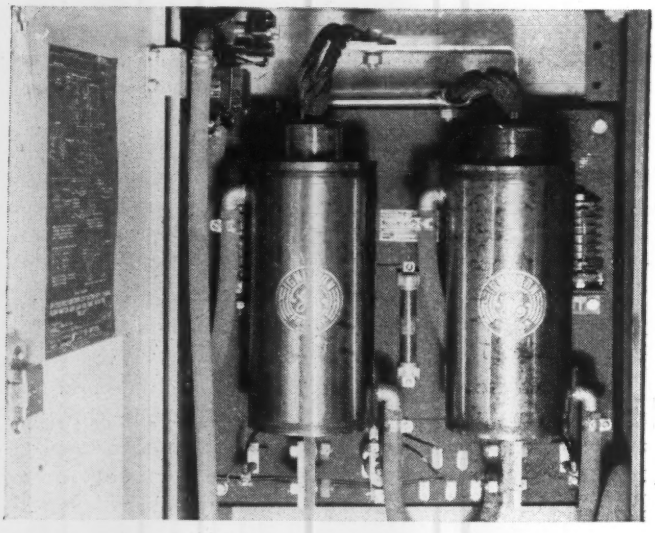


Fig. 13—Above—Ignitron contactor switches resistance welder power on and off

RESISTANCE WELDING: Satisfactory welding of materials such as stainless steel and aluminum is made possible only by the precise timing and heat control of electronic devices. Stainless must be melted at the junction point but must heat and cool through the critical temperature quickly to prevent loss of stainless properties. Aluminum, is a very good conductor of both heat and electricity, but is so soft that a little too much heat will quickly ruin the weld.

To obtain the most effective control, an electronic timer, *Fig.* 11 is employed. If a seam welder which produces a series of pulses rather than a single hot spot is being controlled two timers are utilized. One controls the heating period and the other the cooling period between heat pulses. Then a heat control may be added to determine the phase angle at which the control thyratron and ignitron will fire to produce the desired amount of heat at each pulse, *Fig.* 12. Finally, the large ignitrons themselves are used to pass the actual power current required by the welder, *Fig.* 13. These large tubes are capable of handling tens of thousands of amperes for the short time required to make the weld. They are cooled by a flow of water which circulates in their double shells.

Other types of welders use rectifiers to store up energy in a large bank of capacitors, or in an inductance, and then discharge this energy suddenly into the weld. They are thus able to supply a large amount of energy in a very short time by storing energy from the power line over a period of time, rather than demanding it all at once from the electrical supply.

Wrapper Utilizes Phototube

PHOTOELECTRIC REGISTER CONTROL: Circuits thus far discussed are more or less self-contained electronic equipments operating a particular device. In the case of the photoelectric register control, that is, the registering of printing with some mechanical operation such as cutting or folding printed paper, there is much more freedom of engineering allowed in the over-all application. For instance, for the simplest type, say that of a candy-wrapping machine where the paper moves slowly and may be stopped each time that a bar is to be wrapped, an index mark may be printed along the edge of the sheet. When the mark intercepts the light to the phototube, the paper will be stopped in order that the required operation may take place before the paper is again moved forward.

On the other hand, when the paper moves somewhat more rapidly, it may be drawn forward slightly too much and then, when the register mark reaches the limit of the permitted tolerance (as determined by the position of a contact geared to the knife), the paper may be moved back by a notching action and then permitted to creep forward again.

As speed is increased, it becomes necessary to control the speed of the web accurately so that it will always be cut near the proper point. This can be done completely by electronic means, all the way from the phototube to the thyratrons that supply power to the correcting motor driving a differential to synchronize exactly the speed of the web and cutter. For most precise action at high speeds, a combination of phototubes and a slotted disk may be used to indicate the position of the knife.

DIRECT-CURRENT fans for the Navy have been developed by Westinghouse which use 34 per cent less steel, 30 per cent less copper, 80 per cent less brass and 50 per cent less nickel alloy resistance wire than previous designs. Through reduction in weight these savings greatly simplify shockproof mountings.

Don't Overlook International Markets in New Designs

WITH the prospects of international trade after the war beginning to occupy the thoughts of some of the keenest minds in Washington, the day is not far distant when chief engineers and designers will turn their thoughts and plans in the same direction. Even though the domestic market will remain the primary consideration, far more export trade is likely to be established when the conflict is over than ever has been enjoyed by this country in the past.

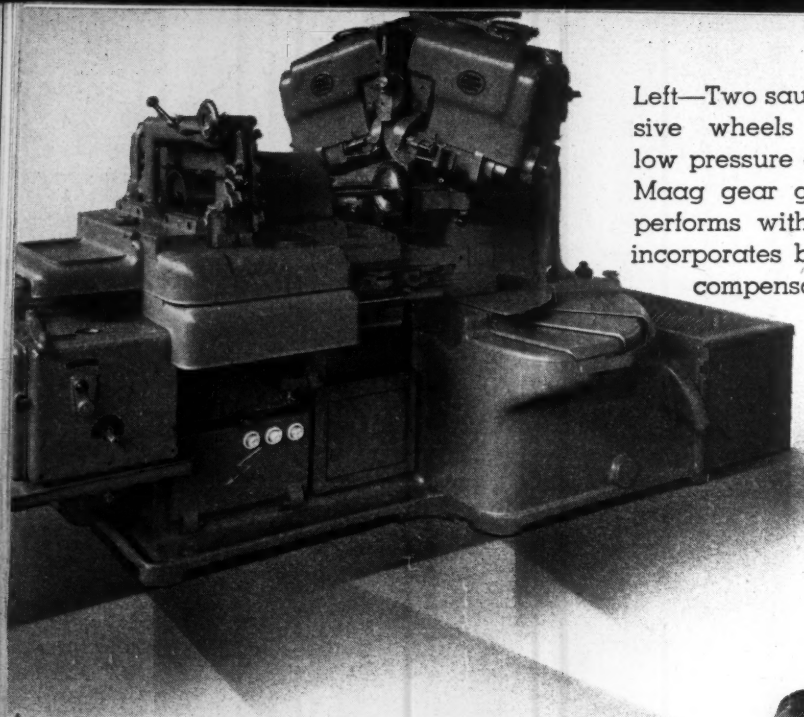
Reasons for this include such factors as the potential abundance of merchant shipping; destruction of manufacturing facilities in war-hit countries; need for importation of raw materials to replenish the "stockpiles" here—with corresponding payments by us in manufactured goods; greatly increased knowledge of world customs and potential markets; desirability of reconstruction in all countries.

Foreign purchasing commissions, set up primarily from a military standpoint, are said to be establishing connections over here with respect to the needs of their respective countries following the war. Among such needs unquestionably will be production equipment, business and domestic machines, turbogenerators, planes, cars, and innumerable other types of mechanical, electrical and automotive equipment, with which many of these countries have had increased experience during the past few years.

What are the implications as far as design of machines is concerned? It seems that in all those cases in which manufacturers might be in position to capture some of this projected export trade, the design of their machines should be sufficiently flexible to command not only a market here but also to create foreign sales outlets. By the increased production necessary it would be possible to keep down costs, or—to use an old but timely slogan—"produce more goods at lower prices".

It would be well for design departments and sales departments to work intimately hand-in-hand as the end of the war comes nearer. There probably never has been a period when design could benefit as much from knowledge of market requirements or when sales staffs could handle to greater advantage the best their companies' designers could produce.

L. E. Jermy



Left—Two saucer-shaped abrasive wheels working under low pressure are employed on Maag gear grinder. Machine performs without coolant and incorporates built-in automatic compensating device

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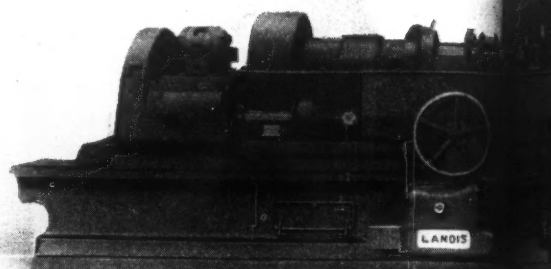

Right — Unique rotary valve makes possible flexible and sensitive control of Anderson hydraulic straightening press. Pressure for straightening work is regulated over a wide no-step range by conveniently located lever shown at right-hand side of knee hole

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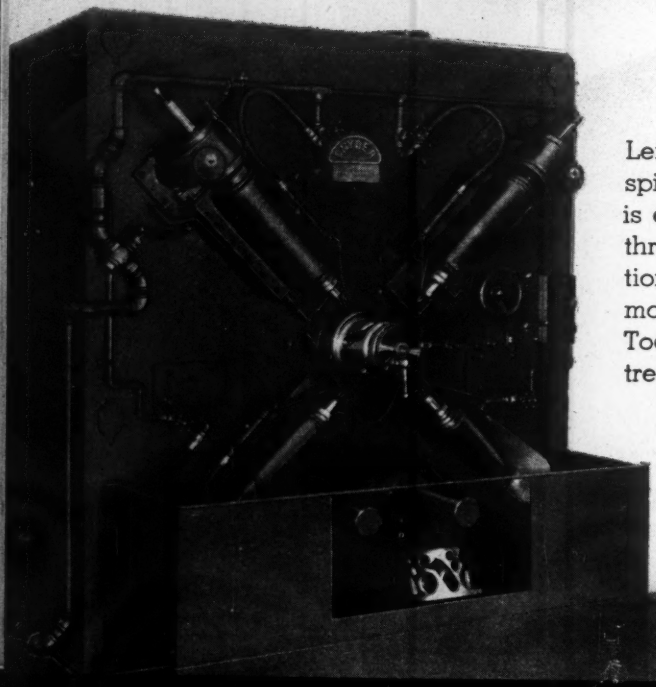
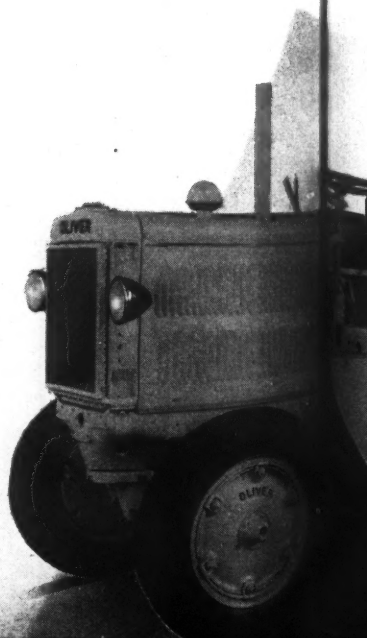
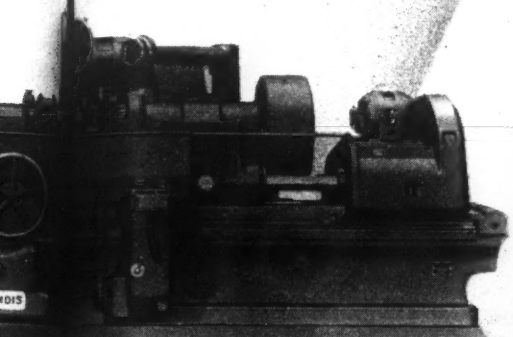
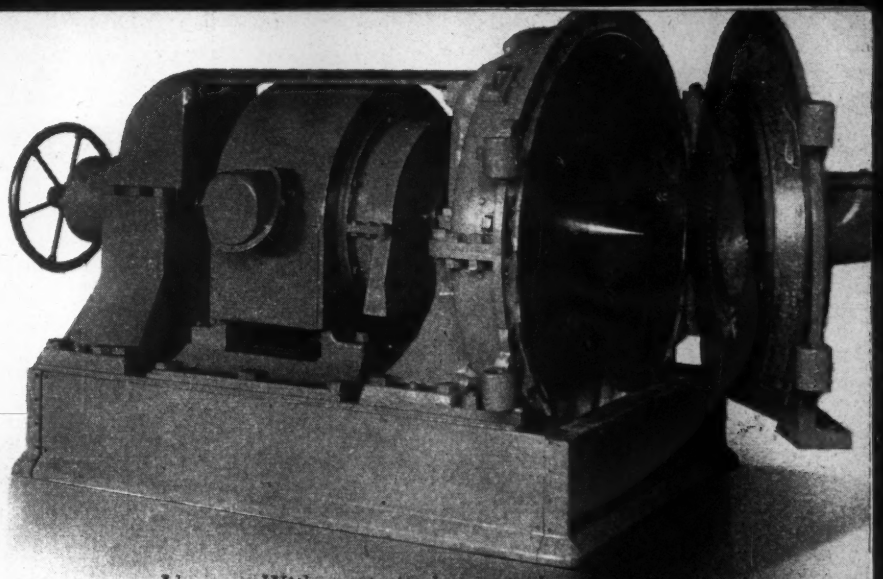


Left—Reciprocation of work fixture spindle of Snyder hydraulic miller is effected by two plunger cylinders through rack and pinion, while rotation of the spindle is through a cam mounted on one of the plungers. Tool spindles are equivalent of heat-treated SAE 6145 as are all gears. Wormwheels are hard bronze



Below— of two work-drive motors is elec synchronized on Landis hydrau kpin grinder. Transverse movem oth work heads is effected through nd pinion. Flood lubrication is e d for work-spindle bearings



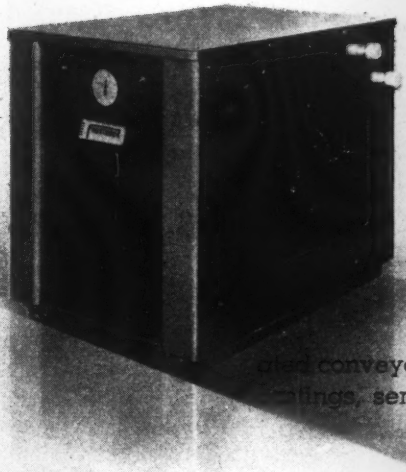


Above—With cast-steel runner head c n tandem ball and self-aligning roller b ings mounted on structural steel base, the Sprout, Waldron rotary disk mill has cast-iron shell and bearing pedestals. Hinged head shell is fitted with tramming plugs for grinding plate alignment

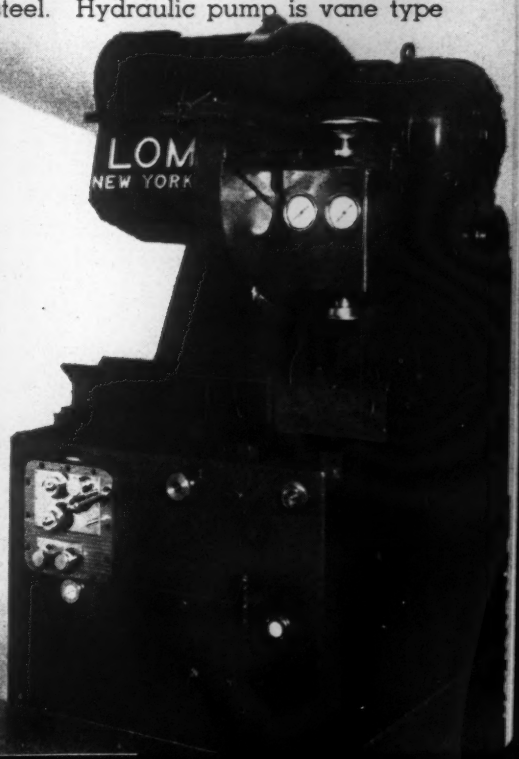
ches Behind th Guns

(For machine listings, see page 222)

Left—Insulation of Frostrode coolant cooler is bulk glass wool held in place by rigid spun glass asphalt-coated board. Compressor, housing, crankcase, pistons, connecting rods and main bearings are electric-furnace nickel iron. Compressor valves are Swedish steel and crankshaft is die-forged steel



Below — Using a counterweighted saw arm, the Loma hydraulic cold saw employs a mono-acting oil cylinder for effecting feed. Hydraulic clamp holds work in place and chips are removed by mechanically operated conveyor. Shafts and gears are SAE 4340 steel; bearings, semi-steel. Hydraulic pump is vane type



Left — Utilizing centrifugal variable-speed type governor, the Oliver industrial tractor employs pressure lubrication for main, camshaft, connecting rod, rocker arm and governor shaft bearings. Using four rings per piston and renewable nickel-iron cylinder sleeves, its main bearings are bronze-back babbitt-lined type

Design Roundups

Powder Metal Proves Economical

POWDER METALLURGY is believed by many to be economical only if large quantities are involved in a mass production set-up. This is an erroneous assumption; many quality parts are being produced from metal powders although the quantities are small. Two examples illustrate this point. In one case 200 parts were required per month. The manufacturer set up for production from metal powder with a reduction in cost sufficient to make the innovation pay in a few months. In the second case, a single order for 20,000 parts permitted their production with a saving of 2 to 3 dollars per part. In both cases the parts weighed but a few ounces apiece.

Designing for Mass Production

WHEN engineers started to tool up new plants for mass production of aircraft engines, they realized that the possibilities for innovations in manufacturing practice were virtually limitless. Radial engines like those built by Wright and Pratt & Whitney hitherto had never been built in volume such as automobile manufacturers understood the word, and there had never been any particular pressure on costs or production time. Tougher steels, wider use of aluminum and magnesium, closer fits, and vastly greater overall finishing of component parts, however, make aircraft engine building a specialized technique.

Nevertheless, machine designers and tool engineers have worked out scores of machining improvements which have lowered costs, speeded production and at the same time maintained precision and quality. Here is a round-up of a few of these ideas, culled from various new plants building radial engines:

A Buffalo plant makes extensive use of Cincinnati Hydrotel profiling machines on such jobs as contouring connecting rods. Four spindles work on as many rods simultaneously, their travel in a horizontal plane automatically controlled by a fifth spindle carrying a guide pin traveling inside a templet formed to the shape of the rod.

A new and unusual design recently was worked out for a machine to mill angular valve clearance holes in the tops of aluminum pistons. This was formerly done by a single-spindle vertical miller, but in the new design a three-spindle unit was developed, with the spindles advancing to the cut after the piston is chucked in the machine.

An interesting improvement in tool design has grown out of difficulties involved in machining cooling fins on the insides of aluminum pistons. High-speed steel finning cutters were tried first, nine individual cutters being "stacked" up on each of two tools, each being keyed to the spindle. Occasional breakage through the keyway proved troublesome and costly, since each of the 18 cutter disks cost around $10, or $180 for the two complete tools. A change was worked out to use mild steel cutters blanked out of cold-rolled steel stock—the cutting points being tipped with a cast, high-speed steel containing boron and applied in the form of welding rod. They can be produced at a cost of $1.50 each, or $27 for the two complete tools. With the softer center, breakage is reduced and machining qualities are equal to the high-speed steel cutters.

Finish grinding of one piston design is complicated by the fact the piston has five different diameters across its face, plus a slight taper next to the ring grooves. Variation from maximum to minimum diameter is only .01-inch and the finish grinding originally was done by properly orienting the piston against a narrow grinding wheel. Now a special grinding wheel has been designed which is the same width as the piston and which can be dressed to the exact contour of the piston wall. Grinding machines are equipped with dressers which by means of suitable templets check the wheel contour regularly and keep it within limits.

Reduction in Vibration Needed

ALTHOUGH MUCH ADVANCE has been made in railway passenger car design, considerable development remains to be effected. According to one railway executive the most important thing needed at this time is improvement in design of car trucks so as to reduce the effect of vibration of the wheels as they travel over rails. This constitutes a problem worthy of the best attention of the design engineer. Light nonferrous metals have made headway in passenger car construction but for freight car construction, apart possibly from certain lines such as special-purpose tank cars and the like, nothing is in sight to stay the strong trend toward greater use of high-tensile, low-alloy steels.

Single Line Nomogram Aids Spring Design

By Carl P. Nachod

Nachod & United States Signal Co. Inc.

IN ARRIVING at the best proportions of a helical spring for a particular job, several preliminary approximations usually must be made. The single line nomographic chart on Page 150 greatly facilitates such calculations and offers distinct advantages over other methods, particularly in the speed with which results may be obtained. Although ordinarily there is required a duplication of scales and of computing secants for nomographic representations involving more than three variables, the chart presented requires only a single computing secant cutting across the scales of all five variables.

Following are the standard round-wire helical spring equations on which the chart is based:

$$P=\frac{\pi d^3 S}{8D} \quad \ldots\ldots (1)$$

$$\delta=\frac{\pi S D^2}{Gd} \quad \ldots\ldots (2)$$

$$c=\frac{D}{d} \quad \ldots\ldots (3)$$

in which P is the load, pounds, to produce a deflection per turn of δ inches, d is the wire diameter and D the mean spring diameter, both in inches, S is the fiber stress in pounds per square inch, not corrected for coiling, G is the shear modulus in pounds per square inch, and c is the spring index.

As has been shown by A. M. Wahl, the actual working stress S_w is greater than the S computed from the foregoing equations due to the curvature of the wire in the helix, or

$$S_w=KS \quad \ldots\ldots (4)$$

where K, the Wahl factor, is a function of the spring index c which may be written

$$K=\frac{4c-1}{4c-4}+\frac{.615}{c} \quad \ldots\ldots (5)$$

An approximation for K derived by the writer is given by the following equation:

$$K=\frac{c+1}{c-.4} \quad \ldots\ldots (6)$$

In constructing the chart the necessary reduction in the number of variables is effected by taking $S=60{,}000$ pounds per square inch and $G=11.5\times 10^6$ pounds per square inch (the value for steel). Because load and deflection are directly proportional to stress, it is a simple matter to adjust the results for working stresses other than those for which the chart was constructed. Substitution of these numerical values in Equations 1 and 2 results in the following equation which, together with Equations 4 and 5, form the basis of the chart:

$$D=\frac{23{,}600\, d^3}{P} \quad \ldots\ldots (7)$$

$$D=\sqrt{61\,\delta d} \quad \ldots\ldots (8)$$

$$D=cd \quad \ldots\ldots (9)$$

It will be noted that there are five variables in Equations 7, 8 and 9, with D and d common to all three equations. These five variables are represented by the five scales on the chart, while Equations 4 and 5 are incorporated in the stress values which appear alongside the spring index scale at the extreme left of the chart.

The aligning secant shown on the chart indicates that a helical steel round-wire compression spring of .1-inch diameter wire wound to one-inch mean diameter will compress .164-inch per turn with a load of 23.6 pounds. Although the uncorrected fiber stress is 60,000 pounds per square inch, the actual fiber stress due to the coiling is 68,700 pounds per square inch.

Design of a spring for a particular stress and for specified load and deflection is readily performed as shown in the following example. Let it be required to design a spring for 50,000 pounds per square inch maximum fiber stress at a load of 120 pounds with a spring index of 8 and a gradient of 50 pounds per inch deflection. From the chart the corrected stress for $c=8$ is 70,800 pounds per square inch. Hence the stress ratio is 50,000/70,800=

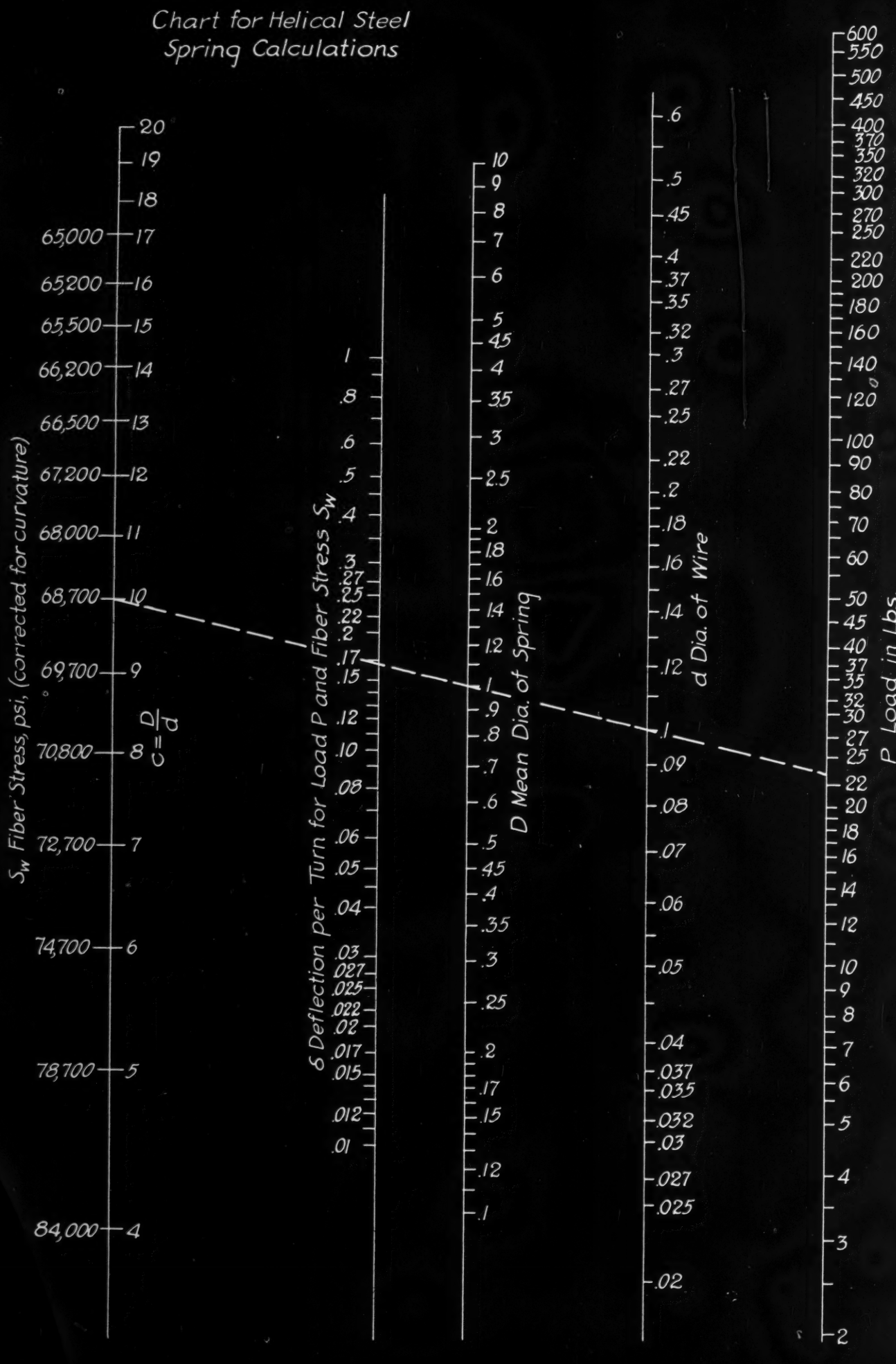


Chart for Helical Steel Spring Calculations
S_w Fiber Stress, psi, (corrected for curvature)
65,000
65,200
65,500
66,200
66,500
67,200
68,000
68,700
69,700
70,800
72,700
74,700
78,700
84,000
$C = \frac{D}{d}$
δ Deflection per Turn for Load P and Fiber Stress S_w
D Mean Dia. of Spring
d Dia. of Wire
P Load in Lbs.

.706. The corresponding load on the chart is therefore 120/.706=170 pounds. A straight line on the chart connecting $P=170$ and $c=8$ gives $d=.24$-inch, $D=1.92$ inches and $\delta=.252$-inch. The actual deflection per turn is therefore $.252\times.706=.178$-inch. In effect this is like taking a stronger spring from the chart and compressing it less for the application. For 50 pounds per inch gradient the number of active turns is $170/(15\times.252)=13.5$.

It should be noted that this chart is subject to the limitations of the equations from which it was constructed. Thus, values are accurate provided the initial pitch angle is less than ten degrees and the deflection per turn is less than one-fourth of the mean diameter.

How the Single-Line Nomogram Is Constructed

THE nomographic chart in this Data Sheet illustrates a method of combining several 3-parallel-line nomograms having some common variables, so that a single line or computing secant across all the scales will solve the several equations they represent, without the usual duplication of scales.

It will be noted that the three helical spring equations (7, 8 and 9 on Page 149) contain 5 variables with D and d in common. As a first step, ignore the constants and solve for a single variable:

$$d^3=DP \quad \ldots\ldots (10)$$

$$D=\delta^{1/2}d^{1/2} \quad \ldots\ldots (11)$$

$$D=cd \quad \ldots\ldots (12)$$

In this form the scale for the single variable will be between the other two, and each scale will be logarithmically graduated increasing upward. The bases will be marked 1 and the tops 10.

Proportioning the Scales

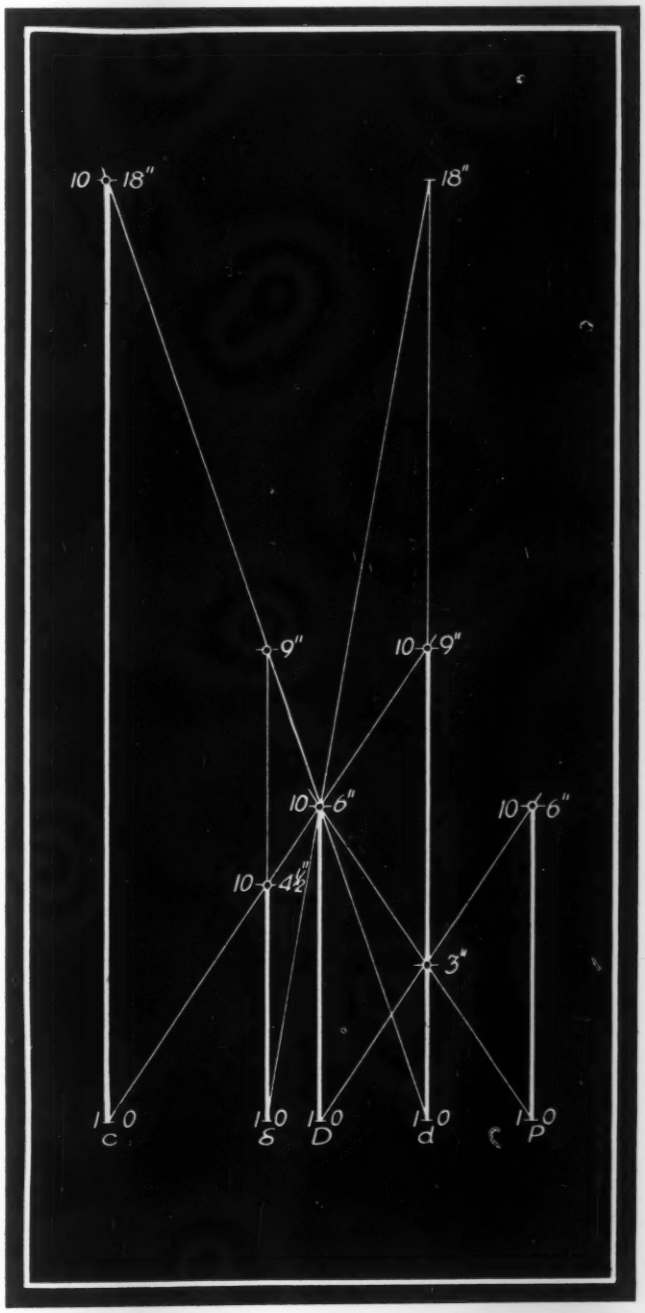
In the accompanying figure take, say, 6 inches as modulus (length for one cycle such as 1 to 10, 10 to 100, etc.) for scales D and P, laying off their parallel scales, say, 4 inches apart for Equation 10. Draw diagonals from $D6$ to $P0$ and $P6$ to $D0$, from the top of one scale to the bottom of the other. Their intersection gives 3 inches as modulus of d and its location midway. However, since d is cubed its modulus is to be multiplied by 3, making it 9 inches, and its top is marked 10.

With D and d determined, find the δ scale from Equation 11 in a similar manner by drawing diagonals from $d18$ through $D6$ to δ, and $d0$ through $D6$ to $\delta9$, which would give 9 inches as modulus for δ, and place it one inch to left of D. Since δ and d are square roots, modulus of d would have to be 18 inches. Taking half of each makes modulus of δ equal to 4½, leaving D and d equal to 6 and 9 inches, as before. Similarly, by drawing diagonals $d9$ through $D6$ to c, and $d1$ through $D6$ to $c18$ it is found, using Equation 12, that c is 3 inches to left of δ and its modulus is 18.

Locating the Scales Vertically

Effect of the constants, which were omitted in Equations 10, 11 and 12, is to slide the scales vertically. Substitute in Equations 7, 8 and 9, say, $D=1$ and $d=.1$, then $c=10$, $P=23.6$ pounds and $\delta=.164$-inch. These will lie in the same straight line across all the scales and thus determine a point on each for the graduations, as shown on the actual chart.

Opposite the values of c those of S_w or 60,000 K, the actual stresses, are marked, values of K being determined from Equation 5.

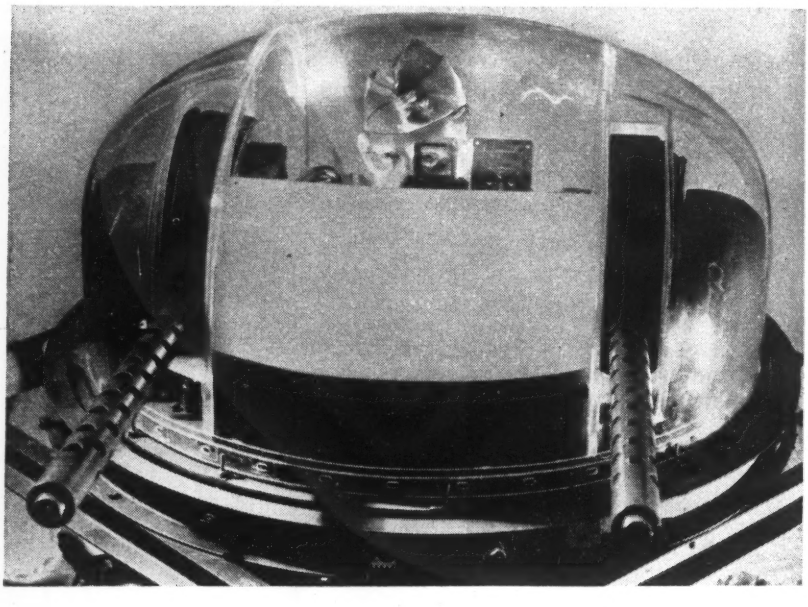


Applications

of Engineering Parts, Materials and Processes

Aids Gun Turret Control

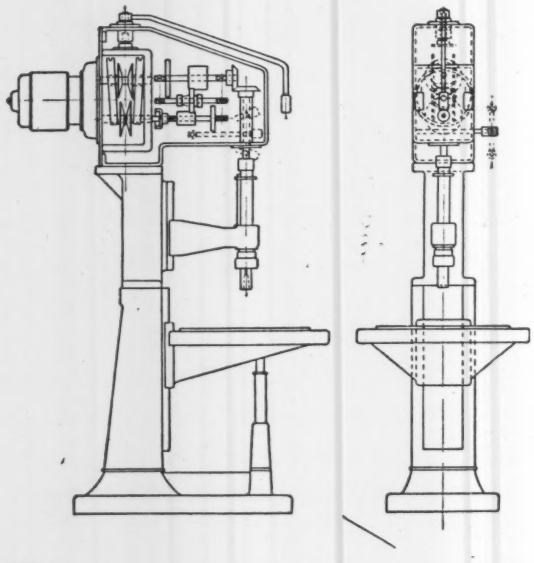
PROVIDING accuracy and high speed of response over a wide range, the amplidyne control enables the gunner in an aircraft turret, right, to maneuver his guns against terrific wind resistance as easily as he would sight a rifle on a target range. Because of its simple construction the amplidyne is proving less vulnerable to bomb impact and shell splinters than other control methods while its operation is not impaired by severe atmospheric conditions at high altitudes.



Cast Crankshafts Developed

REPLACING a forged shaft of .45 per cent carbon steel in a 900-revolutions per minute Cooper-Bessemer diesel engine, the cast crankshaft shown at right is 7 feet 8 inches long. Made of Meehanite, stress relieved but not heat treated, the shaft was tested in an engine operated at 900 pounds per square inch peak pressure for 20,000,000 revolutions, then at 1000 pounds per square inch peak pressure for a further 20,000,000 revolutions without sign of failure.

Pin and journal diameters and crank web thicknesses are identical with those of the forged shaft. However, as much as two-thirds of the weight of the steel ingot from which the forged shaft was made was removed in machining. Using castings, much of this scrapping of material of course is avoided with corresponding savings in man and machine hours.



Building-In a Transmission Mechanism

HITHERTO furnished only as a completely housed unit, the Link-Belt P.I.V. gear shown at left is an integral part of a vertical drill press, the bare mechanism being built into the machine housing. With only three sets of change gears, an infinite number of spindle speeds from 56 to 3600 revolutions per minute is obtainable. Control shaft of the variable speed unit extends just outside the machine housing for mounting the operating lever. A speed indicator plate attached to the front of the gear head is provided with three rows of markings corresponding to the speeds obtained by the combination of the P.I.V. gear and the three change gear sets.

MACHINE DESIGN'S

Materials Work Sheet

Filing Number 10.00

Magnesium Alloys

ASTM No. B107-41T, grades 8, 8X, 9, 9X, 18, 18X
B90-41T, grades 8X, 18, 18X
B91-41T, grades 8X, 9X

AVAILABLE IN:

B107-41T, gr 8, 8X, 9, 9X, 18, 18X . . . Extruded bar, rod and shapes
B90-41T gr. 8X, 18, 18X . . . . . Sheet and Plate
B91-41T, gr 8X, 9X . . . . . Press forgings

Same compositions, not covered by ASTM numbers, are also available in tubing.

ANALYSES:

	Aluminum	Zinc	Manganese
Grades 8, 8X	6.5	1	.2
Grades 9, 9X	8.5	.5	.2
Grades 18, 18X	3	1	.2

Note: Balance is magnesium plus normal impurities. Suffix "X" denotes high purity alloy for improved corrosion resistance.

PROPERTIES

(apply also to grades 8X, 9X and 18X)

ULTIMATE TENSILE STRENGTH

(1000 *psi*)

	Grades 8	9	18
Extruded rod and bar (typical)	44	47	40
(minimum)	40	43	37
Extruded rod and bar, aged (typical)	..	53	..
Extruded shapes (typical)	44	46	39
(minimum)	38	42	35
Sheet and plate, annealed (typical)	42	..	38
(minimum)	37	..	32
hard rolled (typical)	50	..	46
(minimum)	40	..	38
Extruded tubing (typical)	40	..	35
(minimum)	36	..	32
Extruded tubing, aged (typical)	..	42	..
(minimum	..	39	..
Forgings (typical)	42	45	..
(minimum)	38	42	..

TENSILE YIELD STRENGTH*

(1000 *psi*)

	Grades 8	9	18
Extruded rod and bar (typical)	32	35	30
(minimum)	26	29	25
Extruded rod and bar, aged (typical)	..	36	..
Extruded shapes (typical)	30	32	28
(minimum)	23	27	22
Sheet and plate, annealed (typical)	26	..	25
hard rolled (typical)	35	..	34
hard rolled (minimum)	32	..	26
Extruded tubing (typical)	19	..	22
(minimum)	17	..	18
Extruded tubing, aged (typical)	..	29	..
(minimum)	..	25	..
Forgings (typical)	26	30	..
(minimum)	22	26	..

*Stress at which material exhibits a permanent set of .2 per cent.

ELONGATION

(*per cent in 2 inches*)

	Grades 8	9	18
Extruded rod and bar (typical)	15	12	17
(minimum)	12	9	12
Extruded rod and bar, aged (typical)	..	7	..
Extruded shapes (typical)	14	12	15
(minimum)	9	8	11
Sheet and plate, annealed (typical)	10	..	18
(minimum)	8	..	12
hard rolled (typical)	6	..	10
(minimum)	3	..	4
Extruded tubing (typical)	9	..	11
(minimum)	7	..	..
Extruded tubing, aged (typical)	..	5	..
(minimum)	..	4	..
Forgings (typical)	8	6	..
(minimum)	6	5	..

COMPRESSIVE YIELD STRENGTH

(1000 *psi—typical values*)

	Grades 8	9	18
Extruded rod, bar and shapes	20.5	22	20
Extruded rod, bar and shapes, aged	..	33	..
Sheet and plate, annealed	17	..	16
hard rolled	29	..	33

SHEAR STRENGTH

(1000 *psi—typical values*)

	Grades 8	9	18
Extruded rod, bar and shapes	20.5	21.5	19
Sheet and plate, annealed	20	..	21
hard rolled	22	..	21
Forgings	21	22	..

MACHINE DESIGN is pleased to acknowledge the collaboration of American Magnesium Corporation in this presentation.

Materials Work Sheet

FATIGUE ENDURANCE LIMIT

(1000 *psi—typical values*)

	Grades		
	8	9	18
Extruded rod, bar and shapes	17	17.5	15
Sheet and plate, annealed	12.5	..	11
hard rolled	..	..	11.5
Forgings	16	17	..

BRINELL HARDNESS

	Grades		
	8	9	18
Extruded rod, bar and shapes	55	60	50
Sheet and plate, annealed	56	..	54
hard rolled	..	74	71
Extruded tubing	55	..	50
Extruded tubing, aged	..	60	..
Forgings	55	60	..

OTHER PROPERTIES

(*applying to all forms*)

	Grades		
	8	9	18
Specific Gravity	1.80	1.81	1.79
Weight, (lb per cu in)	.065	.0653	.0646
Melting Point, (deg. F.)	1150	1110	1180
Thermal Conductivity (g-cal/sq-cm/sec/deg.C/cm) (100 to 300 deg. C.)	.19	.18	.23
Electrical Conductivity (% of International Annealed Copper Std.)	12.3	10.8	17.2
Modulus of Elasticity, (psi)	— 6,500,000 —		
Poisson's Ratio	— .34 —		

Mean Coef. of Thermal Expansion, (68 to 212 deg. F.) .....—about .0000145 per deg. F.

Mean Specific Heat (68 to 212 deg. F.) .....—about .249 cal/g/deg. C.

Bearing Strength may be taken as 1.6 times the tensile strength, provided the edge distance, in the direction of stressing, is not less than twice the diameter of the hole.

BEND RADII FOR SHEETS

Minimum recommended radii for 90-degree bend in terms of sheet thickness (t) are given below and apply to sheets ranging from .04 to .072-inch thick.

	Working Temperature		
Grade	70 deg. F.	400 deg. F.	600 deg. F.
8 (soft sheet)	5t	3½t	2t
8 (hard sheet)	10 to 15t	5t	3t
18 (soft sheet)	4t	3t	2t
18 (hard sheet)	8 to 12t	3½t	2t

APPLICATIONS

For extremely lightweight moderately stressed structural parts, the extruded forms of these alloys are used to considerable advantage. Such parts as aircraft conduit, special aircraft frame sections, parts of bobbins and sectional warp beams used in the textile industry and typewriter platens are made of magnesium tubing. In the form of sheets, these alloys are employed for parts such as ball bearing retainers, cover plates, spacers, containers, engine cowlings, bus and truck roofs and side panels, pattern plates, etc.

In general, among magnesium aviation parts are oil drain sumps, crankcase blower sections, supercharger housings, intermediate crankcases, diffuser-impeller covers, ducts, instrument panels and housings, floor I-beams, landing wheels, engine housings, oil tanks, doors, automatic pilot parts, wing tips, seats, pedals and control columns.

In the prewar period magnesium was used in vacuum cleaners, sewing machines, hand tools, ventilating fans, pump bases, camera parts, goggle frames, portable conveyors and chutes, and core boxes for foundries.

CHARACTERISTICS

Magnesium is the lightest of the structural metals, has a high strength-weight ratio and is adaptable to modern processes of fabrication such as extruding, die casting, fusion and resistance welding, etc. It has excellent machining properties. Where parts are subjected to abrasive wear, the surfaces affected should be protected by a harder metal, leather, fiber, rubber, etc., depending on the nature of the application. For maximum corrosion resistance, suitable protective coatings must be utilized. Magnesium should not be used in direct contact with such metals as tin, copper, brass, bronze, monel, cast iron or steel in the presence of moisture, as the galvanic couple resulting will accelerate corrosion of the magnesium.

FABRICATION

MACHINABILITY:

All of the magnesium alloys have excellent machining properties. Especially suitable for screw machine work are grades 8 and 18, covered by this work sheet. Magnesium machining requires one-half to two-thirds the power needed for cutting aluminum alloys or brass, one-third that for cast iron and one-sixth that for steel. Tool cutting edges should be kept sharp and tool faces highly polished. Tool clearances are large and relatively fast speeds and feeds are utilized. Parts to be machined are firmly clamped and, where excessive heating is present, a coolant is utilized. To prevent failure of parts due to stress concentrations, sharp inside corners should be scrupulously avoided and generously rounded corners used instead. To guard against fires, accumulation of chips around the cutting machine is not permitted.

FORMING:

Magnesium alloys have less favorable forming properties than metals such as iron, copper and aluminum. They work harden rapidly when formed at room temperature, hence their cold-working possibilities are limited. However, by heating them to between 400 and 700 degrees Fahr., their workability is greatly improved. They should be formed slowly and, in designing forming tools, the relatively high springback of magnesium alloys must be taken into account. Lubricants are employed for drawing operations.

BLANKING AND SHEARING:

These operations require close tool clearances. Tool and die diameter clearance of .003-inch has been found satisfactory in most cases. Stock over about 1/16-inch thick has a tendency to shear with a flaky and rough surface. Use of hold-down pressures and, where feasible, heating of the stock to about 500 degrees Fahr. will improve this condition. Plate is sheared cold up to ½-inch thickness and sawed when heavier. Where an extremely smooth cut is required the plate is sheared and shaved.

Materials Work Sheet

RIVETING:

Magnesium alloys are not used in the form of rivets. Rivets of aluminum alloys with little or no tendency to cause galvanic corrosion of magnesium are preferred. Aluminum alloy 56S in the quarter-hard temper is usually specified for such rivets and requires no heat treatment and quenching prior to driving.

When using a large rivet in thin sheet, the maximum rivet diameter for 56S alloy is three times the sheet thickness. For 2S alloy, 6 times the sheet thickness. When using a small rivet in a thick sheet, the minimum rivet diameter is equal to the thickness of the thickest plate. Minimum distance between rivet centers should be three times the rivet diameter. Minimum distance from edge of sheet to center of rivet should be two times the rivet diameter.

Rivet holes should be drilled or subpunched and reamed, not punched, and there should be about .015 to .03-inch clearance between hole and rivet shank diameter. Insulation of the rivet from the magnesium structure by zinc chromate primer is recommended to prevent possible corrosion.

FASTENING WITH SCREWS:

Coarse-threaded screws with flat or rounded thread tops such as the American National Coarse Series or the British Standard Whitworth are preferred over the finer thread types. Thread length in the magnesium part should be two to three times the diameter of the screw. To minimize stress concentrations at the roots of threads, threaded-in or cast-in inserts of steel or another wear-resisting metal are recommended. To ensure most favorable stress distribution, screws should be more closely spaced than in similar assemblies using ferrous alloys. To hold galvanic corrosion at a minimum, steel screws should be either galvanized or cadmium plated. Under vigorous corroding conditions, screws should be dipped in zinc chromate primer or a joint-sealing compound. Washers aid to distribute stress and should be about 1/3 the hole diameter in thickness, 2½ to 3 times the hole size in diameter. Steel washers, cadmium plated or galvanized, or 56S aluminum alloy are recommended.

TORCH WELDING:

Grade 18 has good torch welding properties, grade 8 is fair in this respect and grade 9 is poor. It is possible, to a limited extent, to torch weld different magnesium alloys to each other providing the difference in alloying percentage is small. Cast and wrought alloys can be torch welded together most successfully when their compositions are identical. However, it is not yet possible to weld magnesium to other metals. Butt-welded joints are most suitable; lap welds and other types, not permitting thorough removal of the welding flux, should be avoided because of the danger of corrosion. Oxyacetylene flame and special welding flux are recommended.

ELECTRIC SPOT WELDING:

Magnesium alloys lend themselves well to spot welding. Different alloys can be spot welded to each other, but cannot be spot welded to other metals. Sections to be welded should be of nearly the same thickness, but if this is not possible, the thicker section should preferably be not more than twice as thick as the thinner section. Distance between the spots should be at least eight times and preferably sixteen times the sheet thickness (minimum ¼-inch and ½-inch respectively). Distance of spots from the edge of the sheet should be at least four times and preferably six times the sheet thickness (minimum 3/16-inch and 5/16-inch respectively).

ARC WELDING:

Recently an arc-welding process, using a tungsten electrode surrounded by a shield of helium gas, has been developed for joining magnesium alloys. This process is applicable to a wide range of magnesium alloys and results in higher-strength joints than are possible by the torch-welding process. Because it does not require a welding flux, the new process is not restricted to butt welds but may also be used for joining magnesium parts by lap, fillet and edge welds.

RESISTANCE TO CORROSION

Commercially pure magnesium and many of its alloys resist the action of most outdoor atmospheres rather well, although some surface attack of the uniform-etching type occurs. However, unless moisture is trapped in crevices or low spots, no structurally serious corrosion will occur. Marine or seacoast locations are more corrosively active than inland locations and may cause severe attack. Unless it is known that the environment and conditions of service are not detrimental to magnesium, it is advisable to protect the parts with a painting system which will withstand severe exposure conditions.

Action of solutions of many alkaline materials, borates, fluorides, chromates, chromic acid and hydrofluoric acid is well resisted by magnesium alloys. Solutions of most other mineral acids and of the salts of these acids are definitely corrosive.

A number of coatings, applied by chemical treatment and frequently supplemented by paint coats, are available for protecting the surfaces of magnesium alloy members against corrosive attack. They are, however, so numerous and varied, that any attempt to list and evaluate them in the limited space of this Work Sheet would be impractical. For specific data on such coatings a magnesium producer should be contacted.

GALVANIC CORROSION

In most environments, magnesium has a higher electrolytic solution potential than the other structural metals. Joints of magnesium with most other metals, therefore, require protective insulation under conditions conducive to galvanic corrosion, that is when moisture is present in the joint. Lack of such insulation will result in severe corrosion adjacent to the dissimilar metal. The severity of galvanic corrosion resulting from couple with various dissimilar metals is listed below. "1" indicates a minimum and "5" indicates a maximum of attack on the magnesium member.

Rating	Dissimilar Alloys
1	214, 220, 52S, 53S, 56S aluminum alloys
2	43, 356, 2S, 3S aluminum alloys
3	112, 195, 355, 17S, 24S aluminum alloys; galvanized mild steel, phosphate-coated mild steel, cadmium-plated brass 60-40
4	Cr-Mo (SAE X-4130) steel, cadmium-plated steel, stainless steel 18-8; copper, tin bronze, aluminum-bronze, brass 60-40, monel, cast zinc-base alloy (3Cu, 5Al).
5	Cast iron, cold-rolled mild steel, cadmium-plated mild steel.

Materials Work Sheet

GALVANIC CORROSION (*cont'd.*)

Insulating materials vary in efficiency and care should be used in their selection. Under conditions of outdoor exposure, a good method is the use of insulating layers of zinc chromate primer or of nondrying sealing compounds. In more severe cases, the use of these materials combined with gaskets is recommended. About the best joint sealers commercially available at present are mixtures of zinc chromate, aluminum powder, inert filler, oils and thinner.

Much can be done in the actual design of the part to make it less susceptible to corrosion. For example, pockets which can catch and retain water, or closed containers without ventilation where water may condense, are to be rigorously avoided. Where such pockets must exist, provision for simple drainage should be made.

DATA ON STOCK FORMS

Extruded Rod and Bar

ROUND, SQUARE, HEXAGONAL AND RECTANGULAR

Magnesium round bar is an extruded round shape of ⅛-inch diameter and larger. Square bar is an extruded shape of ⅛-inch across flats or larger. Hexagonal bar is an extruded hexagonal shape of ¼-inch across flats or larger. Square edge rectangular bar is an extruded shape of rectangular cross section, the minimum size being ⅛-inch by 3/16-inch.

ROD AND BAR TOLERANCES

Diameter or Across Flats (inches)	Tolerance Plus or Minus (inches)
Up to 0.500	.007
0.501 to 1.000	.010
1.001 to 2.000	.012
2.001 to 3.000	.015
3.001 to 4.000	.018
4.001 to 5.000	.020
5.001 to 6.000	.022
6.001 to 7.000	.025
7.001 to 8.000	.030
8.001 to 9.000	.035
9.001 to 10.000	.040
10.001 to 11.000	.045
11.001 to 12.000	.050

Extruded Round Tubing

Extra Heavy iron pipe sizes can be approximated in magnesium tubing in the following sizes:

Extra Heavy iron pipe size (inches	Magnesium Tubing — O. D. (inches)	I. D. (inches)	Wall (inches)	Magnesium Weight (lb. per ft.)
½	.875	.579	.148	.26
¾	1.063	.767	.148	.32
1	1.313	.953	.180	.50
1¼	1.625	1.219	.203	.70
1½	1.875	1.469	.203	.81
2	2.375	2.043	.220	1.16
3	3.500	2.860	.320	2.48
4	4.500	3.860	.320	3.23
5	5.500	4.750	.375	4.65

Extruded Round Tubing

COMMERCIAL WALL THICKNESS TOLERANCES

The following tolerances represent maximum deviation of mean wall thickness from the nominal. Mean wall thickness is determined as the average of any two measurements taken at 180 degrees from each other on any circumference of the tube. Individual readings may deviate from the mean by plus or minus ten per cent.

Wall Thickness (inches)	Outside Diameter (inches) — Up to ¾	Over ¾ to 1¾	Over 1¾ to 3	Over 3 to 5	Over 5 to 7½
Up to .049	.007	.007	.007	....	....
.050 to .120	.007	.008	.011	.015	....
.121 to .203	.008	.009	.013	.018	.025
.204 to .300	....	.011	.017	.023	.031
.301 to .375	....	.014	.023	.035	.043
.376 to .500	....	.018	.035	.047	.053

Extruded Round Tubing

COMMERCIAL OUTSIDE DIAMETER TOLERANCES

Round tubing is available in sizes from $\frac{3}{16}$-inch to 7½ inches outside diameter and in wall thicknesses from .022-inch upwards. The following tolerances apply to the mean of two readings on the diameters taken at right angles to each other at any point along the length of the tube. Individual readings (for ovality) may deviate from the nominal by an amount equal to twice the tolerances of this table:

Nominal O. D. (inches)	Tolerance (inches)
Up to ½ incl.	.008
Over ½ to 1 incl.	.011
Over 1 to 2 incl.	.015
Over 2 to 3 incl.	.018
Over 3 to 4 incl.	.023
Over 4 to 5 incl.	.027
Over 5 to 6 incl.	.031
Over 6 to 7½ incl.	.037

Rolled Sheet

COMMERCIAL SIZES

Grade	Thickness (inches)	Maximum Size (inches) Width	Length
8X	.016-.019	20	72
	.020-.039	24	96
	.040-.063	30	120
	.064 and heavier*	36	144
18X	.016-.019	20	72
	.020-.031	24	96
	.032-.039	30	144
	.040 and heavier*	36	144

*In this range of thickness, the widths and lengths within the maximums indicated can only be produced if the maximum weight of a finished sheet is not more than 120 pounds.

Sheet is obtainable in hard rolled and annealed tempers up to and including .102-inch (10 gage) thick. From .102 to .25-inch thick, sheet is available in the annealed and "as hot-rolled" condition. In thicknesses greater than .25-inch, sheet is available in the "as hot-rolled" condition only.

MATERIAL DESIGNATIONS

EXTRUDED ROD, BAR AND SHAPES

ASTM	SAE	AMS	Army Air Forces	Navy Dept.	Amer. Mg. Corp.	Dow Chem. Co.
B107-41T gr 8	520	.....	.....	.....	AM57S	J
B107-41T gr 8X	520	4350	11335	M-314	AM-C57S	J-1
B107-41T gr 9	...	.....	.....	.....	AM58S	O
B107-41T gr 9X	...	.....	.....	.....	AM-C58S	O-1
B107-41T gr 18	...	.....	.....	.....	AM52S	FS
B107-41T gr 18X	52	.....	.....	.....	AM-C52S	FS-1
SHEET AND PLATE						
B 90-41T gr 8X	511	.....	11338	47-M- 2 gr 8	AM-C57S	J-1
B 90-41T	510	4380/4381	11340	47-M- 2 gr 18	AM-C52S	FS-1
TUBING						
.....	...	.....	11332	44-T-35 gr 8	AM-C57S	J-1
FORGINGS						
B 91-41T gr 8X	531	4350	11345A	46-M-13 gr 8	AM-C57S	J-1
B 91-41T gr 9X	532	4360	11321A	46-M-13 gr 9	AM-C58S	O-1

Rolled Plate

AVAILABLE SIZES

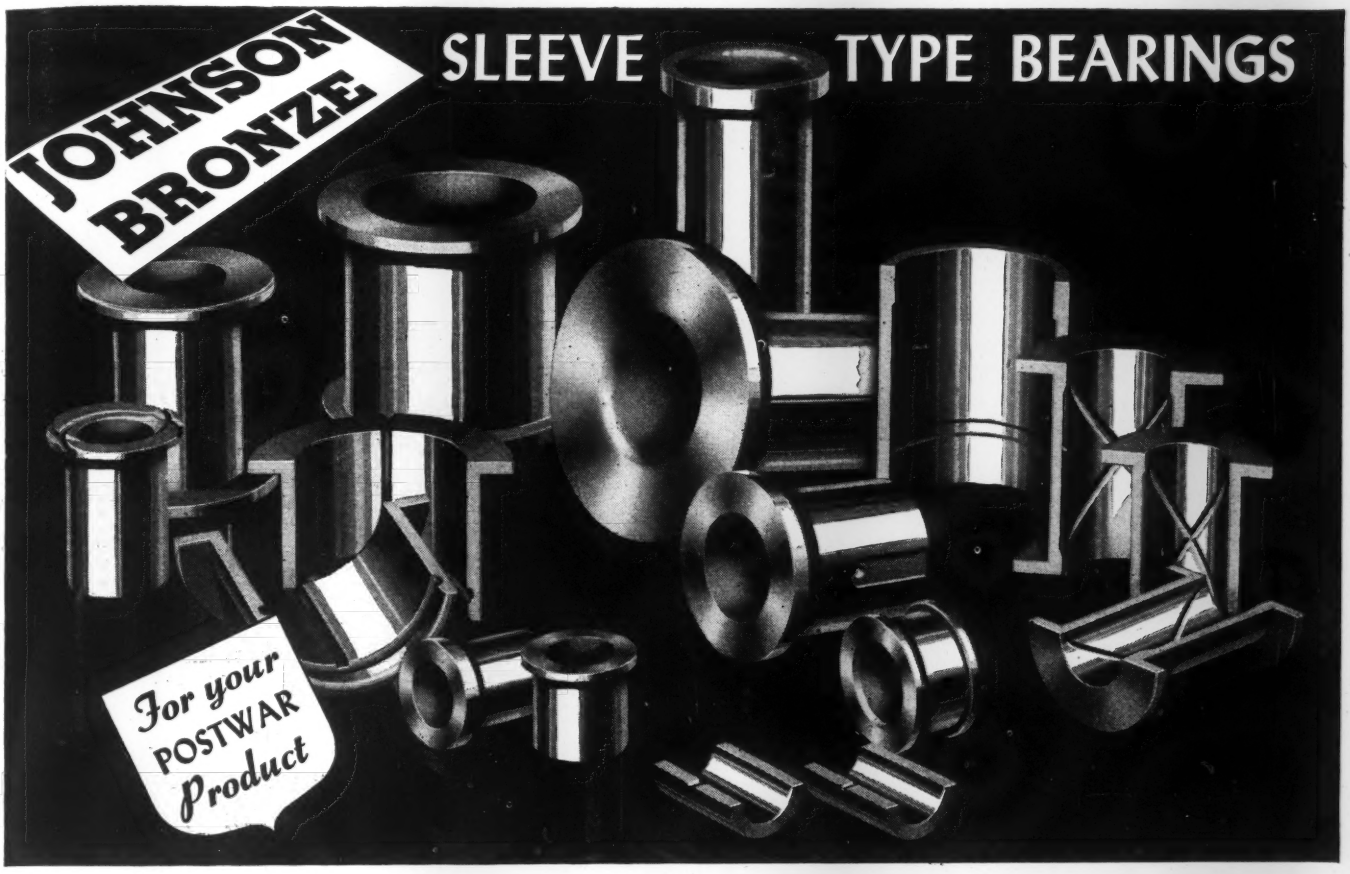
Plate is available in widths up to 36 inches and lengths up to 144 inches, provided the weight per piece does not exceed 120 pounds.

Rolled Plate

COMMERCIAL TOLERANCES

Thickness (inches)	Size Range (inches)	Applying To	Tolerance (inches or %)
.251-0.500	.....	..... Thickness	± 5% of thickness
.501-1.000	.....	..... Thickness	± 4% of thickness
1.001-3.000	.....	..... Thickness	± 3% of thickness
.251-0.500	All dimensions	Width, Lgth. (sheared) §	Plus $\frac{3}{8}$
.251-3.000	Up to 10	Width, Lgth. (sawed)	± $\frac{1}{32}$
.....	Over 10 to 36	Width, Lgth. (sawed)	± $\frac{1}{16}$
.....	Over 36 to 130	Width, Lgth. (sawed)	± $\frac{3}{32}$
.251-0.500	Diam. 5 to 18	Circle Diameter	± $\frac{1}{32}$
.....	Diam. over 18	(sheared circles)	± $\frac{3}{64}$

§Minimum width—18 inches.



Cast Bronze Bearings *for* Long Life

SLEEVE TYPE BEARINGS

Cast Bronze Bearings
Cast Bronze Graphited
Sheet Bronze Bearings
Sheet Bronze Graphited
Bronze and Babbitt Bearings
Steel and Babbitt Bearings
Steel and Bronze Bearings
Ledaloy!
Self-Lubricating Bearings
Electric Motor Bearings
Automotive Bearings
Bronze Bars
Bronze Castings

Any Type
Any Size
Any Quantity

● When you design your new product for tomorrow's market it will pay you to investigate the advisability of using CAST BRONZE bearings.

You gain several distinct advantages in cast bronze. In the first place few bearings deliver the smooth, quiet, efficient performance for so long a time as cast bronze. Properly designed and installed, they will usually outlast the motive unit in which they are used. The initial cost is comparatively low, they are easy to get and easy to replace.

It is not a difficult matter to build this kind of service into your product. Simply call in a Johnson Sales Engineer. Permit him to review your applications, to make recommendations based on facts, free from prejudice. Our more than thirty-five years of exclusive bearing experience plus the fact that we produce ALL types of sleeve bearings enables us to give you the correct answers to your bearing problems. There is a Johnson Sales Engineer as near as your telephone . . . ready and willing to serve you.

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SLEEVE BEARING HEADQUARTERS

The MOST COMPLETE SLEEVE BEARING SERVICE in the WORLD

525 S. MILL STREET NEW CASTLE, PA.

PROFESSIONAL VIEWPOINTS

" . . . articles followed with interest"

To the Editor:

I have followed with interest the articles by R. S. Elberty entitled "The Shape of Things To Come" which appeared in the August, September, October and November issues of MACHINE DESIGN.

If these articles are available in pamphlet form, I would appreciate receiving three copies.

—G. C. WEINGARDT, *Development Engr.*
The Swartzbaugh Mfg. Co.

This four-part series by Mr. Elberty is available in limited quantity in reprint form. Copies will be furnished to readers on request, with the compliments of MACHINE DESIGN.—ED.

" . . . not losing cost consciousness"

To the Editor:

Your editorial in the September issue of MACHINE DESIGN certainly finds its echo in the experience of all open-minded and forward-looking executives in the engineering field. While under present emergency war conditions the element of cost is put secondary to that of getting production quickly and in volume, the development of new devices for use in peacetime must be accomplished with a definite emphasis upon low cost manufacture.

Under the most rosy kind of peacetime conditions we cannot expect the volume of wartime dollar production. This means more competition for the available market, which will go to those organizations that are not losing their production cost consciousness.

—C. E. SCHIRMER, *Chief Engineer*
Hoist and Crane Div.
Robbins & Myers Inc.

". . . calculating beam supports"

To the Editor:

Referring to the article "Supporting Continuous Beams", by A. B. Cox, which appeared in your September issue, may I say that it discusses an interesting design problem which has been given very little attention in textbooks? The elasticity of continuous beam supports has been recognized as a source of error in the calculation of bending moments. Some attempts have been made to remedy this condition in the case of certain aircraft structures by the use of approximation methods where the beam has a variable moment of inertia.

The introduction of engine frame flexibility into the calculation of opposed piston crankshaft bending moments provides an example which has a convenient analytical solution. In this case the classical theorem of three moments becomes a "theorem of five moments", so that when the loads are central and all spans are of equal length:

$$M_{n-1}+4M_n+M_{n+1}+\frac{6EIf}{l^3}(M_{n+2}-4M_{n+1}+6M_n-4M_{n-1}+M_{n-2}) = -\frac{3l}{8}(P_n+P_{n+1})-\frac{3EIf}{l^2}(P_{n+2}-P_{n+1}-P_n+P_{n-1}) \quad (1)$$

which assumes a constant value of f at every support. This equation is simply an elaboration of the general theorem described in detail on pages 111-114 of Timoshenko's *Applied Elasticity:*

$$M_{n-1}l_n+2M_n(l_n+l_{n+1})+M_{n+1}l_{n+1} = -\frac{P_n a_n(l_n^2-a_n^2)}{l_n} - \frac{P_{n+1}b_{n+1}(l_{n+1}^2-b_{n+1}^2)}{l_{n+1}}+6EI(\beta_n-\beta_{n+1}) \quad (2)$$

where $\beta_n=(h_n-h_{n-1})/l_n$, $\beta_{n+1}=(h_{n+1}-h_n)/l_{n+1}$.

The symbols appearing in the equations designate the following quantities:

$n-1$, n, $n+1$. . . . = Number assigned to each support
M_{n-1}, M_n, M_{n+1} = Bending moments at supports $n-1$, n, $n+1$, . . .
h_{n-1}, h_n, h_{n+1} = Vertical distances of the supports $n-1$, n, $n+1$, . . . from a horizontal datum line
P_n, P_{n+1} . . . = Concentrated loads
l_n, l_{n+1} . . . = Length of spans
a_n+b_n . . . = l_n, etc.
I = Moment of inertia of beam section assumed constant for all spans
E = Modulus of elasticity, pounds per square inch
f = Deflection of support per pound reaction force, assumed constant for all supports

Some of these quantities are shown in *Fig.* 1.

The generality of the method used to obtain Equation

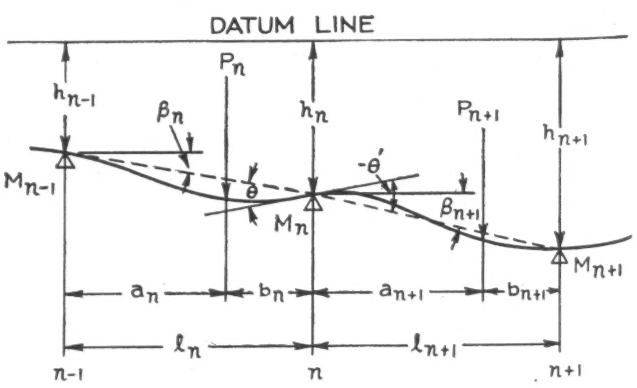
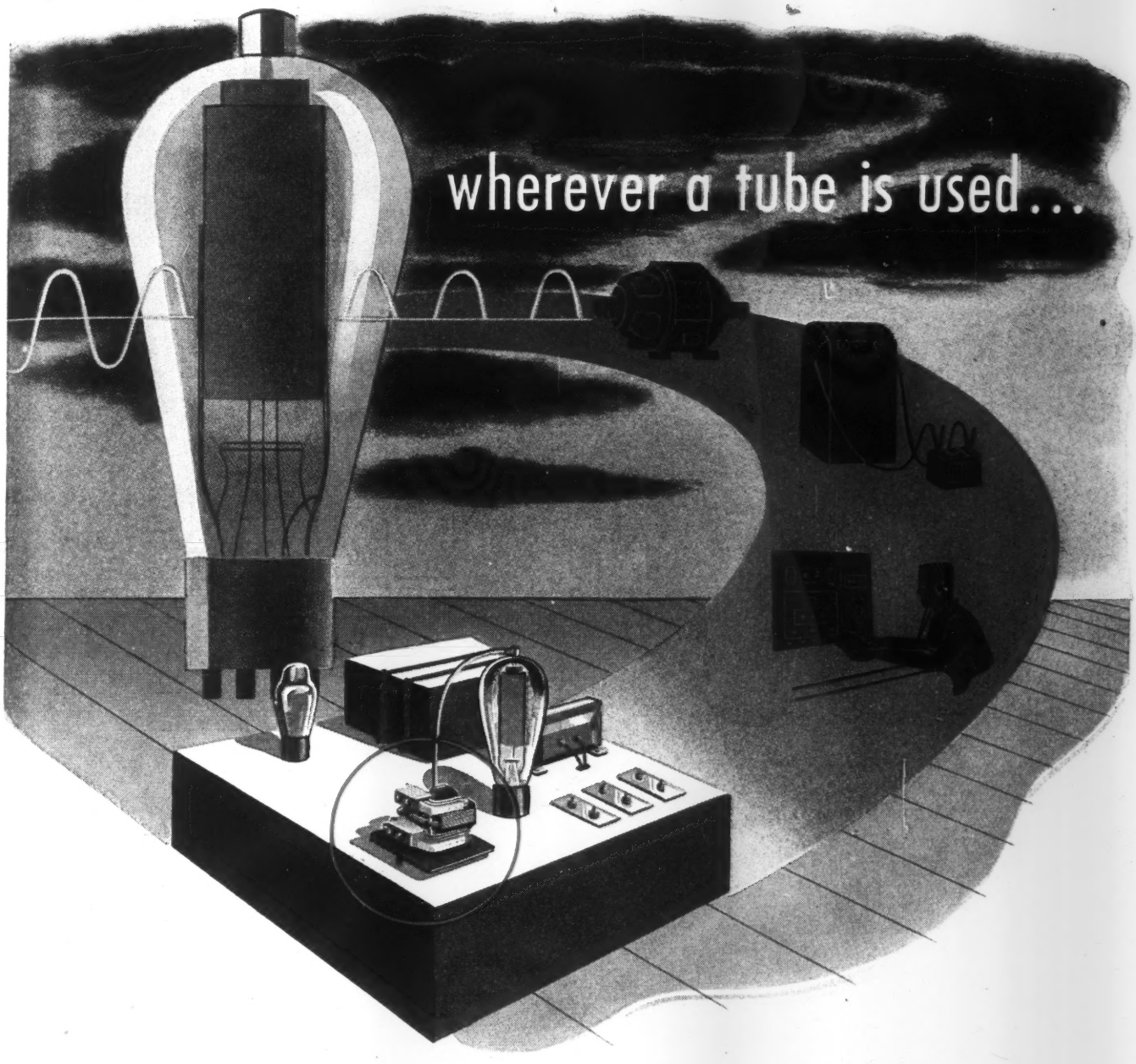


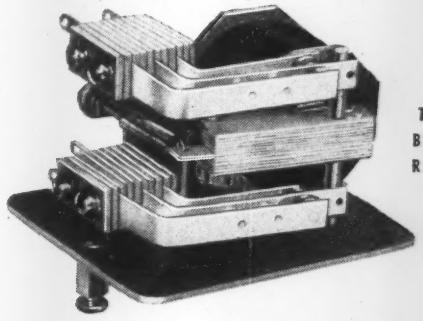
Fig. 1—Loading on a continuous beam



THERE'S A JOB FOR *Relays* BY GUARDIAN

★ Wherever the rectifier type of tube is used, generally there's a job for a relay . . . a RELAY by GUARDIAN . . . in secondary and/or primary circuits where double pole, double throw "on and off" switching is desirable.

Typical of such a relay is the Guardian Type B-100. This double pole, double throw relay is equipped with silver contact points having a capacity up to 1500 watts, 60 cycle non-inductive A C.; and in A.C. primary circuits of any inductive power supply delivering up to and including 1 Kw. Standard coils operate on 50-60 cycle A.C., 110 volts, consuming approximately 8½ VA. Coils available for other voltages. Write for Bulletin OF-112 showing standard relay types.



TYPE B-100 RELAY

Electronic rectification, long used to convert A.C. to D.C. power, is now coming into use to operate variable speed D.C. motors . . . battery chargers, etc. In such applications, the type B-100 relay shown above is often used.

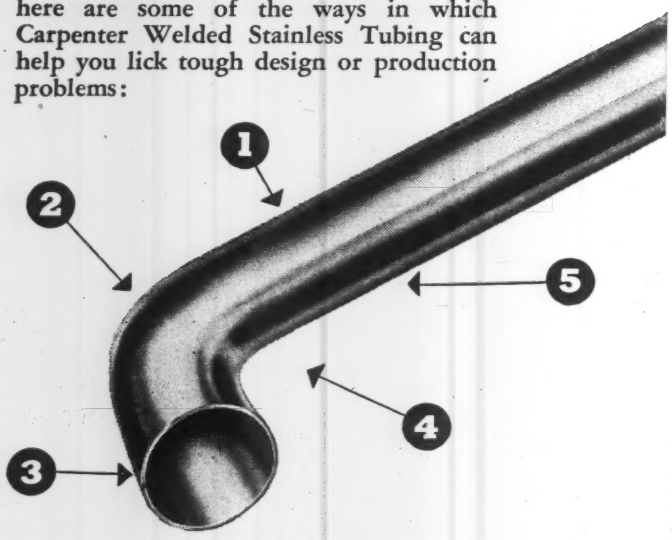
GUARDIAN ELECTRIC

1601-P W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

How these Uniform Tube Walls
help to Improve Products and Speed Production

Welded Stainless Tubing . . . with uniform walls . . . was pioneered by Carpenter. And here are some of the ways in which Carpenter Welded Stainless Tubing can help you lick tough design or production problems:



1 LIGHTER GAUGES can be used without sacrificing strength.

2 EASIER BENDING, flanging, cutting, welding, etc. with uniform walls.

3 NO "THIN SPOTS" to give corrosion or heat scale a foothold.

4 WEIGHT IS SAVED by using less metal to sustain a given weight or pressure.

5 MORE COMPACT ASSEMBLIES possible with strong and uniform walls in lighter gauges.

Take advantage of Carpenter's diversified experience with production-engineering problems involving the use of tubing. Drop a line to our Metallurgical Department when you need technical data—or when you could use fabricating help.

At Your Fingertips . . .

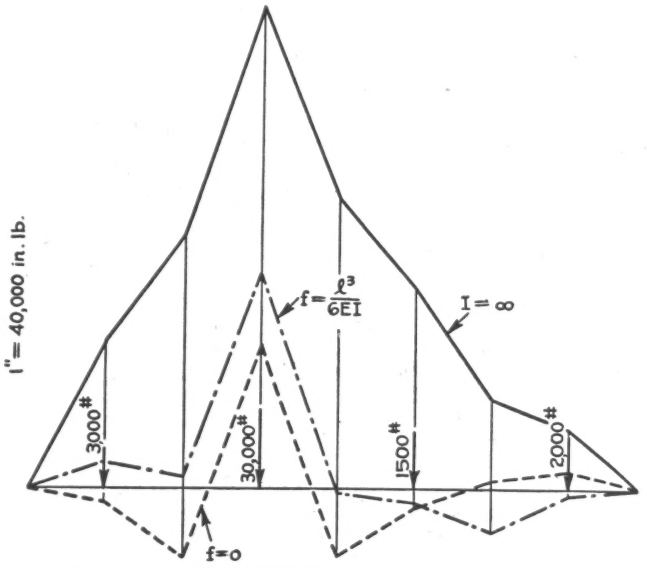
Here is useful information to help you get the most from Carpenter Welded Stainless Tubing. A note on your company letterhead will bring you this data on physical properties, diameters and gauges, special shapes, specialty tubing, etc. Ask for your free copy today.

The Carpenter Steel Company
Welded Alloy Tube Division • Kenilworth, N. J.

Carpenter
WELDED
STAINLESS TUBING

1 is not limited to simple cases where I is constant, but the solution is facilitated when the loads are central and the spans are of equal length and moment of inertia.

Fig. 2 shows the results of calculations made for a continuous beam of four 12-inch spans with (1) $f=0$, (2)



	R_0	R_1	R_2	R_3	R_4
$f=0$	-994	19,092	18,321	-1,190	1,271
$I=\infty$	10450	8,875	7,300	5,725	4,150
$f=l^3/6EI$	1,935	15,436	15,014	4,673	-558

12" SPANS WITH CENTRAL LOADS

Fig. 2—Continuous beam calculations

$I=0$, and (3) $f=l^3/6EI$. The equations for determining the moments, obtained from Equation 1, are:

Case 1:

$$M_{n-1}-4M_n+M_{n+1}=-\frac{3l}{8}(P_n+P_{n+1})$$

Case 2:

$$M_{n+2}-4M_{n+1}+6M_n-4M_{n-1}+M_{n-2}$$
$$=-\frac{l}{2}(P_{n+2}-P_{n+1}-P_n+P_{n-1})$$

Case 3:

$$M_{n+2}-3M_{n+1}+10M_n-3M_{n-1}+M_{n-2}$$
$$=-\frac{l}{2}\left(P_{n+2}-\frac{1}{4}P_{n+1}-\frac{1}{4}P_n+P_{n-1}\right)$$

Each of the foregoing equations yields three equations by assigning to n the values 1, 2 and 3.

The solution of Mr. Cox's problem is obtained by the same methods as were used to construct Equation 1 from Equation 2 with the added advantage that any elasticity of beam and supports can be considered without further mathematical analysis; these quantities simply depend on EIf. In most cases it is preferable to assume a value for the elasticity of the supports rather than try to estimate the reactions from calculations for the extreme cases. The disparity of such results is emphasized in *Fig.* 2 where the three cases are compared.

It is significant that the continuous beam problem involving elasticity of both beam and supports can be solved

They wanted wire, tube and sheet in

Split-Hair Sizes

...and found the strong, corrosion-resistant metals they sought among the INCO Nickel Alloys

Are you looking for metals in ultra-fine sizes for essential applications today...or for your new products after the war?

Do you want...in addition to the split-hair size ...metals with strength, toughness and high resistance to corrosion?

Then take a look at these examples of how INCO Nickel Alloys can be produced in practically any form or size you may want for applications that need a rustless corrosion-resisting material with high mechanical properties...

THE WIRE shown in the magnified photo above knotted around two strands of human hair is 0.0009" thick. A pound would stretch 80 miles. It is a regular commercial product of the Driver-Harris Co.

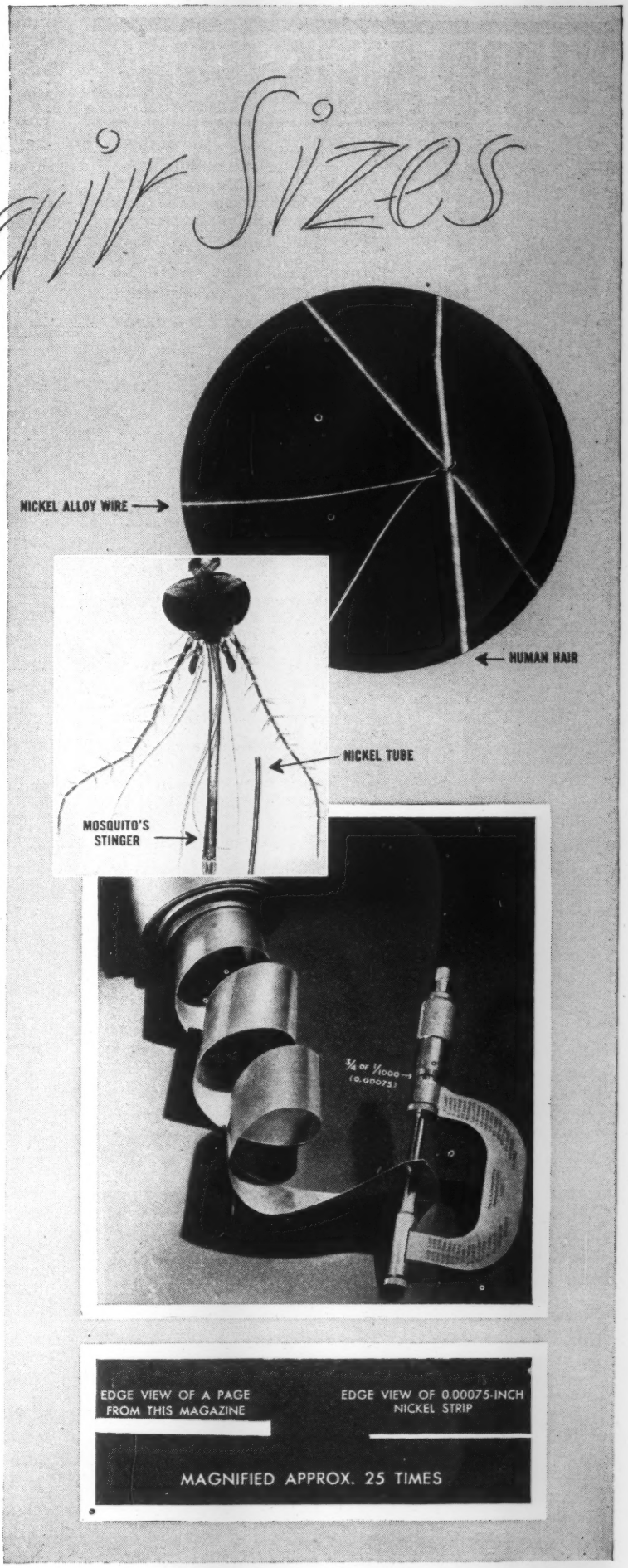
THE TUBING, smallest ever drawn, is compared with a mosquito's stinger. Outside diameter of this nickel tube is 0.0019"; inside diameter, 0.0004". Superior Tube Company produces commercial tubing in INCO Nickel Alloys as small as 0.010", outside diameter.

THE STRIP is .00075" thick . . . one-third the thickness of this page. It would take more than 1300 strips to equal an inch. This nickel strip is made by Somers Brass Company for regular commercial use.

In addition to their group properties of high strength, toughness and corrosion resistance, individual INCO Nickel Alloys have *specialized* properties for applications requiring high-temperature strength, special hardness, resilience, etc.

"Tremendous Trifles" a booklet which discusses the properties, sizes and forms of 8 INCO Nickel Alloys will be sent to you on request. Please give Company, Name and Title. Address:

THE INTERNATIONAL NICKEL COMPANY INC.
67 Wall Street, New York 5, N. Y.



INCO NICKEL ALLOYS

MONEL • "K" MONEL • "S" MONEL • "R" MONEL
"KR" MONEL • INCONEL • "Z" NICKEL • NICKEL
Sheet... Strip... Rod... Tubing... Wire... Castings

PUMP AIDS of 1944

Essential data on the installation, operation and maintenance of modern pumping equipment. Prepared by Blackmer engineers for those who buy and use rotary pumps.

These Bulletins will be sent FREE upon request

304: FACTS ABOUT ROTARY PUMPS — Diagrams of operating principles of swinging vane type rotary pumps.

111: DIRECT-CONNECTED ROTARY PUMPS — Low capacity, high efficiency pumping units of wide industrial application.

115: SANITARY PUMPS—Important data for food processing plants.

120: MARINE PUMPS: The advantages of "Bucket Design" swinging vane principle in the Marine field.

205: ROTARY HAND PUMPS — Safety, efficiency and economy in handling stockroom liquids.

400: EZY-KLEEN STRAINERS (made by Blackmer) The importance of protection for positive displacement pumps.

SER 1: PUMP MAINTENANCE CARD— Handy check list, in card form, to hang near each pump.

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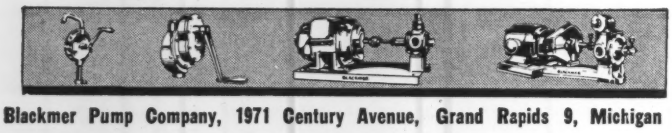
100: TRUCK PUMPS—Power-take-off and self-powered pumping units for tank trucks.

Your "pump file" is not complete without these bulletins. Sign and mail the coupon NOW.



Blackmer Pump Company, 1971 Century Avenue, Grand Rapids 9, Michigan

Please send bulletins checked— No. SER-1 ☐

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*Signed*_____ *Title*_____

*Company*_____

*Address*_____

satisfactorily by analytical methods even when it may be necessary to use estimated values for the elasticity of the supports. This procedure has the appearance of placing the ignorance factor in another part of the calculation. However, in most cases the nature of the problem usually suggests a method of approximating the elasticity of the supports with a fair degree of accuracy. The reactions for the intermediate case need not necessarily lie between those for the extreme cases.

—K. E. Bisshopp
Fairbanks, Morse & Co.

" . . . credit for discovery"

To the Editor:

On Page 118 of the November issue of Machine Design, friction cutting as developed by Arthur Schwartz of Bell Aircraft Corp. is discussed.

Some of the information given therein is not quite accurate, and we take this method of correcting it. We have been making high-speed sheet metal cutting band saws for the automotive industry for many years. These machines, running at 1200 revolutions per minute, give a blade speed of approximately two miles per minute and have been recommended for sheet metal sawing up to ¼-inch thick. It remained for Mr. Schwartz to discover that by certain operating technique, hard or soft steel up to 1-inch thick can be sawed on this machine. To him goes the credit for this discovery. Your article states that this machine was "developed by Mr. Schwartz" which is not the case. The machine was developed by ourselves.

—C. E. Tannewitz
The Tannewitz Works

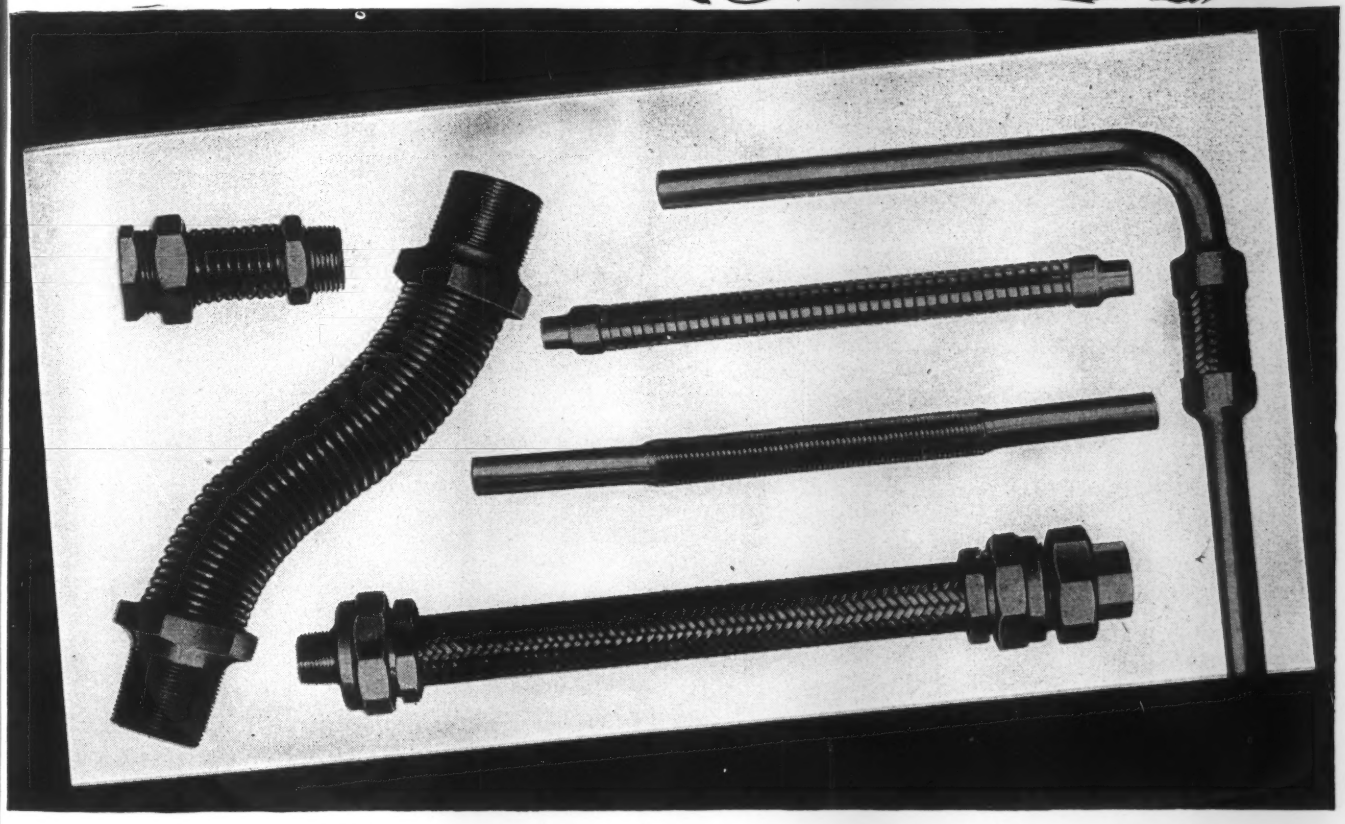
Machine Design apologizes for having made the error of crediting the original design of the machine to Mr. Schwartz.—ED.

They Say . . . .

"Management must prepare now for war contract cancellation and the necessary inventory adjustments that go with the cessation of hostilities. Frozen inventories, such as happened in 1921 could spell disaster for postwar employment. Management must formulate its postwar relationships with respect to its employees. Labor has well enunciated postwar plans of its own, and management's job is to make certain it has equally good or better plans." —John R. Bangs.

"We in management cannot base our future plans on the thesis that some bright sprite or bevy of sprites is about to invent a mechanism certain to regulate customers and prevent fluctuations. Planning on the basis of theory is not a substitute for preparing on the basis of experience. We in management know only too well that a full order book must bear the costs of a lean order book. Depression losses are boom costs."—Enders M. Voorhees.

"IT'S THE MOST RELIABLE METAL TUBING WE KNOW OF"



They all agree that it is . . .

And when production-conscious executives must have *absolute, 100% tightness* plus long life in flexible metal tubing, they usually specify American *Seamless* Flexible Metal Tubing. For past experience has shown them that this deluxe product will flex millions of times without failure.

American *Seamless* is all-metal, made from *seamless tubes.* It has neither joints, welds, laps, seams nor packing at which leaks might develop. It combines the flexibility of rubber hose, the dependability of metal, the strength of rigid pipe.

Another interesting feature—you can get American *Seamless* Tubing in practically any workable metal of your choice.

Throughout industry, American *Seamless* is almost a password. Countless war plants are using it to convey air, fuel, water, chemicals, cutting compounds, refrigerants, propane and butane, manufactured freon, ammonia, oxygen, hydrogen, nitrogen, acetylene and many other fluids. They use it too for controlling vibration and for connecting moving or misaligned parts.

Whatever your requirements you'll most likely find that we have a flexible metal tubing or hose that will help you do the job just a little bit better.

Why not investigate?

43200

American Seamless—corrugated from seamless rigid tubing . . . pressure tight as the metal tube from which it is made.

ANACONDA

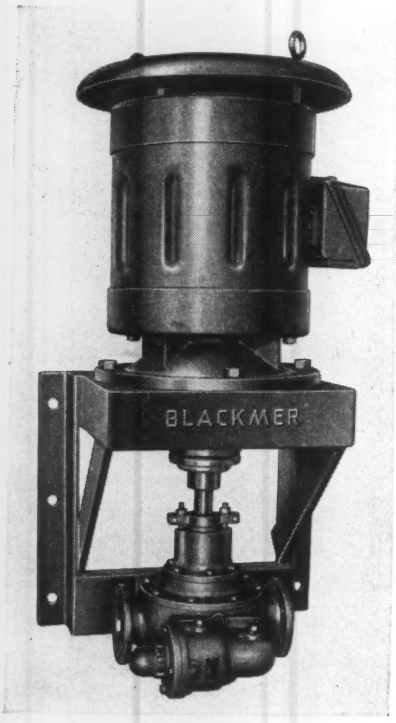
American Metal Hose

AMERICAN METAL HOSE BRANCH OF THE AMERICAN BRASS COMPANY • General Offices: Waterbury 88, Conn.
Subsidiary of Anaconda Copper Mining Company • In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ontario*

New PARTS AND MATERIALS

Rotary Pump Announced

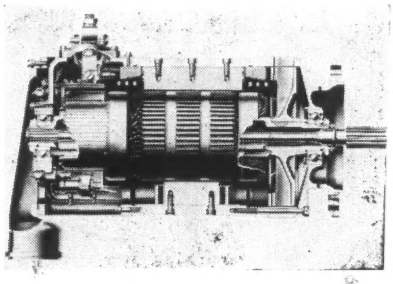
FOR use as original equipment on certain types of liquid processing machinery, a new rotary pumping unit with built-in relief valve—used also for handling Navy lube oil—is being offered by Blackmer Pump Co., Grand Rapids, Mich. This unit operates on the "bucket design" (swinging vane principle), and has a capacity



of 50 gallons per minute at a discharge pressure of 20 pounds per square inch. It is direct connected by means of a flexible coupling to a three-horsepower motor which drives the pump at 870 revolutions per minute. Bearings are internal antifriction type. In order to conserve space, the motor is supported by a bracket or "shelf" of welded steel plate and bolted to a bulkhead. The pump is mounted vertically on the base of the bracket, permitting free access for lubrication and adjustment.

High-Output Generator Offered

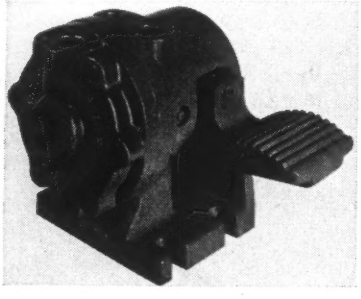
OF INTEREST to the aviation and allied industries is the recently announced generator developed by Eclipse-Pioneer division, Bendix Aviation Corp., Teterboro, N. J. Suitable for both auxiliary and main engine application, this P-2 generator will produce a full rated load of 200 amperes at 30 volts continuously (6 kilowatts) over a speed range varying from 5000 to 10,000 revolutions per minute. To provide satisfactory operation at low cruising speeds, the generator delivers three-quarters of its rated output at speeds as low as 4400 revolutions per minute. Adequate cooling has been provided by permitting circulation of air through hollow armature shaft. A floating type of flexible torque drive shaft is internally splined to the tubular armature shaft at the commutator end of the unit and held in place by a lock ring. An integral drive spline is provided on the drive end of the flexible torque drive shaft which extends through the back head and engages the engine driving member, thereby



absorbing engine torsional vibration and compensating for any slight drive misalignment. The generator weighs 36 pounds, and the frame measures 12 5/32 inches from the alloy steel mounting flange to the back end, and is 6 inches in diameter.

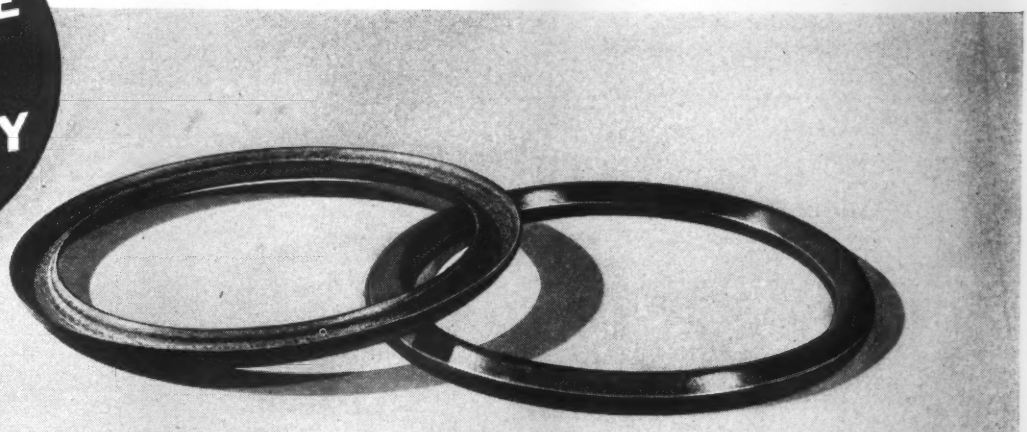
Foot-Operating Valves

DESIGNED for use on all types of pneumatic equipment such as air holding devices on lathes, air vises, operating cylinders, etc., Anker-Holth Mfg. Co., 332 South

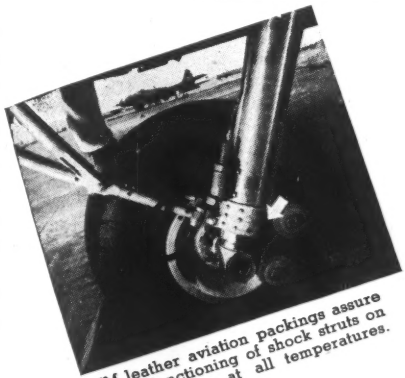


Michigan avenue, Chicago 4, has introduced its new foot-operating valve. It is available in sizes from ¼-inch to ½-inch, and is of the disk type. The pedal is easy to

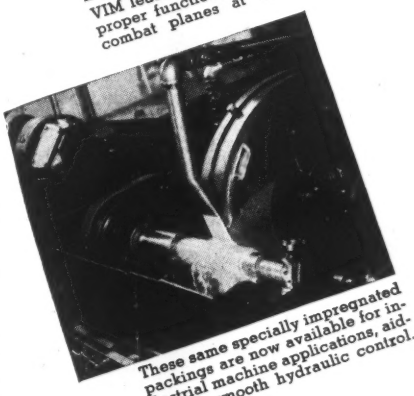
NOW AVAILABLE TO INDUSTRY



-these VIM aviation-type leather packings



VIM leather aviation packings assure proper functioning of shock struts on combat planes at all temperatures.



These same specially impregnated packings are now available for industrial machine applications, aiding in smooth hydraulic control.

To aid the Army and Navy Air Forces in their winterization program, a specially impregnated type of VIM leather packing for aircraft hydraulic use was developed more than a year ago.

After exhaustive tests on shock struts in arctic regions, it was adopted by the Army and Navy for all combat planes. Orders piled in, taxing our production facilities. To meet the enormous demand for this vital material, our Aviation Packing Department was enlarged, and has tripled its former output.

All planes are now "winterized" for safe flying, and with our increased manufacturing capacity, it is possible for us to offer this same type of improved packing to industry generally.

These are "V" packings, impregnated with synthetic resin, making them impervious to any type of oils used as the hydraulic medium. They can be used almost universally for this purpose—for low pressures, or up to 16,000 PSI, and at temperatures from minus 65° to 175°F.

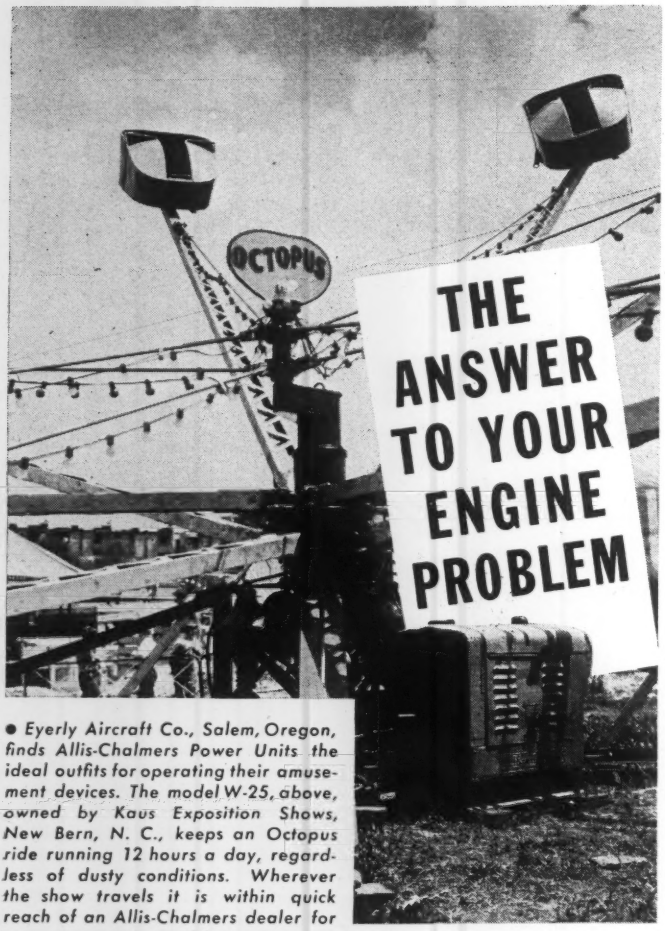
Manufacturers of hydraulic equipment will undoubtedly be interested to test these packings against the types now being used. For data on this new aviation type packing, available for the first time to industry, write our Leather Engineering Department.

E. F. HOUGHTON & Co.

303 W. LEHIGH AVENUE, PHILADELPHIA

Sales and Service offices in all principal cities

HOUGHTON'S *Engineered* VIM *Leather Packings*



• *Eyerly Aircraft Co., Salem, Oregon, finds Allis-Chalmers Power Units the ideal outfits for operating their amusement devices. The model W-25, above, owned by Kaus Exposition Shows, New Bern, N. C., keeps an Octopus ride running 12 hours a day, regardless of dusty conditions. Wherever the show travels it is within quick reach of an Allis-Chalmers dealer for any necessary servicing or parts.*

ALLIS-CHALMERS INDUSTRIAL ENGINES ARE ADAPTABLE TO MANY APPLICATIONS

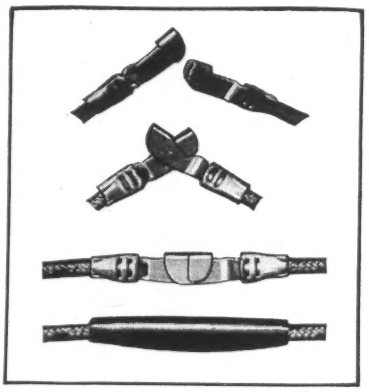
If you are casting about for an engine to power your equipment — one that will stand up under the toughest conditions, that will perform economically and with equal ease on peak or intermittent loads ... investigate Allis-Chalmers engines. Lower priced than other units of comparable displacement and horsepower, they weather any hard going ... from the heavy work of driving rock crushers and shovels to the dusty conditions encountered running amusement rides. They are the same engines that now power thousands of Allis-Chalmers tractors — many of which are with our armed forces in the mud of Italy, the jungles of the Pacific ... wherever there's need for hard-hitting tractor power — on the fighting fronts and at home.

Service facilities are available everywhere! Any Allis-Chalmers agricultural or industrial dealer can supply parts for these engines to users of your equipment. Plan on using these units on your Post War machines. Write now stating your problem. We will be glad to offer suggestions and make recommendations.

ALLIS-CHALMERS
TRACTOR DIVISION · MILWAUKEE · U. S. A.
POWER UNITS
5 SIZES 15 TO 110 B. H. P.
• GASOLINE
• DISTILLATES
• NATURAL GAS
• BUTANE

operate and is returned by means of a spring. When pedal is pushed down and the foot removed, it returns to neutral but the work is held until the pedal is again pushed down.

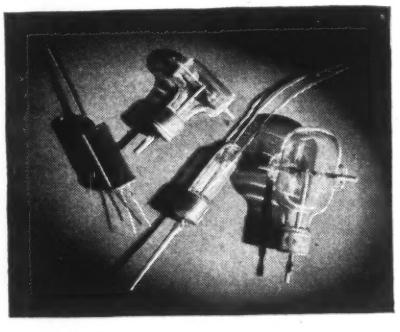
Solderless Splicing Terminal



ANNOUNCED by Aircraft-Marine Products Inc., Dept. O, 1521 North Fourth street, Harrisburg, is a solderless splicing terminal which affords a quick positive splice for connecting wires until intentional quick disconnection is desired. To make a connection only two identical parts are required, eliminating the necessity of stocking and identifying more than one part. Tensile strength of the splice is greater than that of the wire itself, and the assembly may be easily and quickly uncoupled. A four-point "knife-switch" wiping action assures minimum contact drop through the coupling, and gives a perfect electrical connection. Contour of the assembly is such that the sleeving slips on easily and is held firmly in place.

Four New Vacuum Type Switches

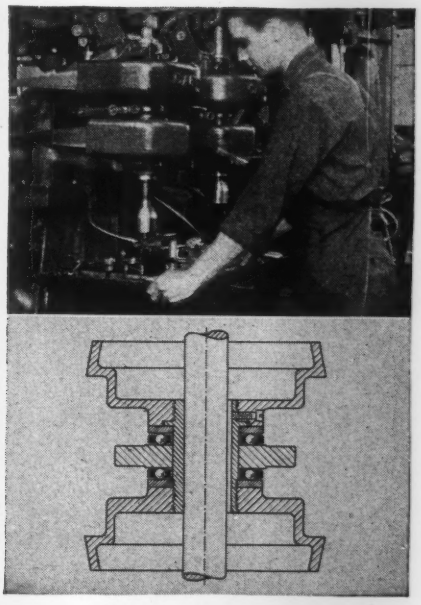
FOR a variety of radio and industrial switching applications, General Electric Co., Schenectady, N. Y., has announced four new vacuum switches which can also be adapted to oil or water-immersed operations. Because of the enclosed construction they are applicable to hazardous installations where fire and explosion are a constant



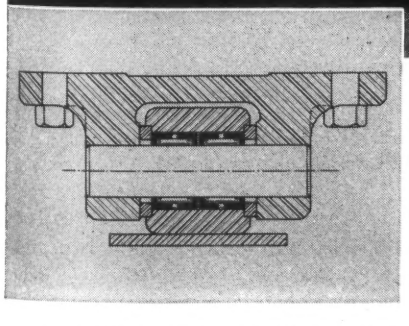
risk such as in flour mills, magnesium finishing rooms, and similar dust-laden atmospheres. Two of the new switches are designed also for high-altitude applications. Since contacts are mounted in a vacuum they are relatively free from effects of corrosion and arcing, and are unaffected by dirt or oxidation. The vacuum-type construction gives the switches a high-current rating for their size and per-

IN THE NEWS
WITH TORRINGTON BEARINGS

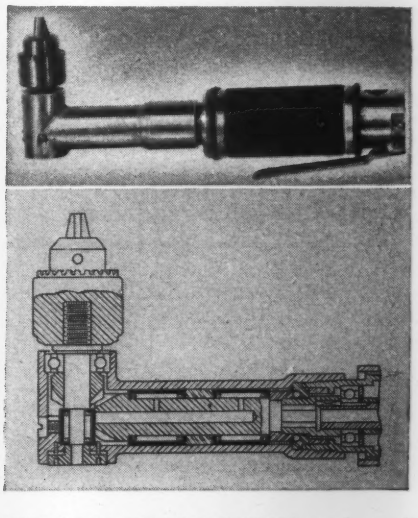
NAKED HULLS GROW INTO HUGE PBY Naval Patrol Bombers as they pass along the conveyor system of the production line at the Consolidated Vultee Aircraft Corporation. The hulls are supported on cradle-like dollies which move the ever-increasing load smoothly to its completion while removable sectional platforms provide ready access to the superstructure of the airplanes. To safeguard the vital wheel axles of the conveyor dollies so that the heavy load will be carried steadily and safely and without time-consuming stoppages, the makers of the conveyor system selected Type NCS Needle Bearings for their high capacity and low friction coefficient.



TAPPING OPERATIONS are done swiftly and accurately with this Garvin No. 2-X Duplex Automatic Tapper manufactured by the Western Machine Tool Works. The builders of this machine selected Torrington Ball Thrust Bearings for application on the spindle between the forward and reverse driving friction cones, as shown in the cross-section, because their sturdy construction and high accuracy could withstand the repeated shock loading which the application required.



"WORLD'S LARGEST" are these cold storage doors made by the Jamison Cold Storage Door Company for a 67° below zero cold chamber at Wright Field. To help support and lend ease to the operation of these colossal doors, a Needle Bearing equipped floor roller assembly has been applied to the bottom of the hinge sides, as shown in the cross-section, to provide ease of manual operation.

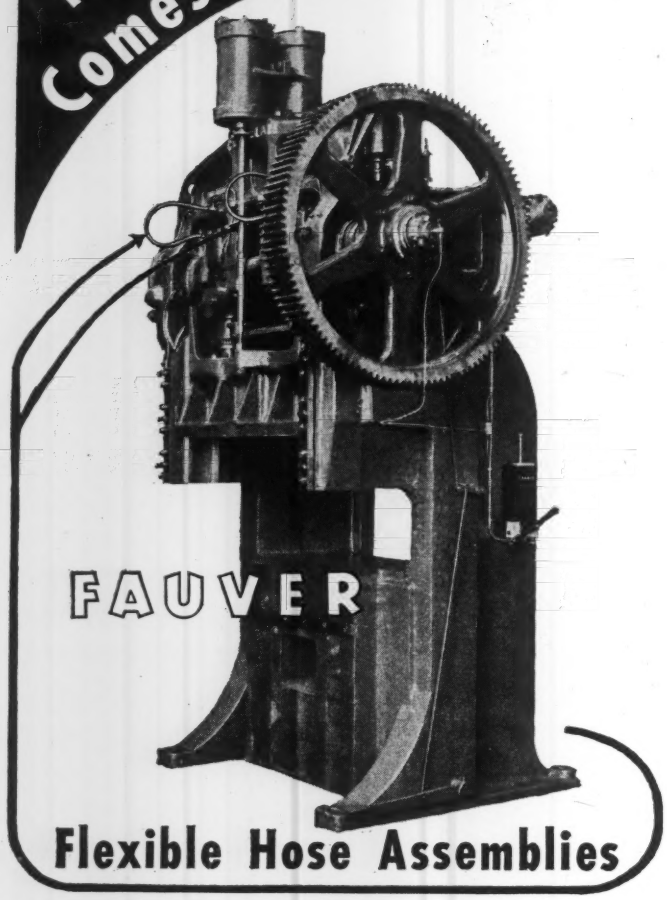


RIVET HOLES IN TIGHT CORNERS and small openings are easily drilled with this pneumatic angle drill made by the Chicago Pneumatic Tool Company. Because of their small size and high load capacity NCS Needle Bearings were selected to carry the load on the shaft of these compactly designed tools, as illustrated in the accompanying cross-section of the drill.

A COMPREHENSIVE LINE OF STANDARD ANTI-FRICTION Bearings—straight roller, tapered roller, needle, and ball—is offered by the Bantam Bearings Division. For new or unusual bearing problems, the assistance of Torrington-Bantam's engineers is especially valuable. Years of experience in the design and application of special bearing styles stand back of their recommendations. Whenever you need engineering counsel on standard or custom-built bearing types, TURN TO TORRINGTON.

ARMY E NAVY
TORRINGTON BEARINGS
STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL
THE TORRINGTON COMPANY · BANTAM BEARINGS DIVISION
SOUTH BEND 21, INDIANA

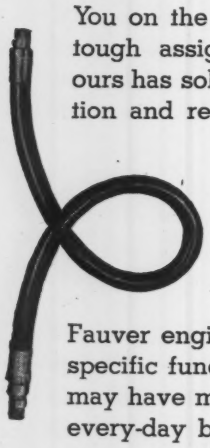
KNOW-HOW Comes with the Years



Flexible Hose Assemblies

have been faithfully serving American industry on machine tools in peace and in war since 1922.

You on the industrial front have given us some tough assignments, but your experience plus ours has solved these problems to speed production and reduce shut-downs.



Together we've licked the bogie of constant vibration, temperatures to 225° F., hose and connections with burst tests up to 25,000 lbs., constant flexing between moving parts.

Fauver engineers know the right assemblies for specific functions. Finding new applications you may have missed or thought too difficult is their every-day business.

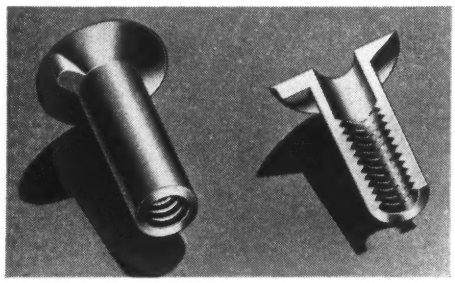
Write for Hydraulic Hose Catalog

J. N. FAUVER CO.
43 W. Hancock Ave. DETROIT, MICH.

mits them to handle enough power to operate equipment at greatly reduced voltages. Operating without auxiliary contactors or relays, the switches can be used on installations where space is at a premium as in airplanes. No self-contained coil or other operating mechanism is built into the switches. Air or liquid bellows, a rod-linkage system, or almost any other means can be used to operate switches of this type. An external fulcrum is eliminated by the use of a flexible diaphragm, transmitting movement to contacts and acting as a natural fulcrum point for the operating arm. Contacts close without vibration, making possible the mounting of these switches on or near delicate instruments.

Threaded Tubular Rivets

PRIMARILY for attaching de-icers to airplanes, the use of the Rivnuts developed by The B. F. Goodrich Co., Akron, O., has been expanded to include industrial applications. The Rivnut is an internally-threaded and counterbored tubular rivet which can be "headed" by a riveting tool while working entirely from the "other" side, making possible the fastening of parts on otherwise un-

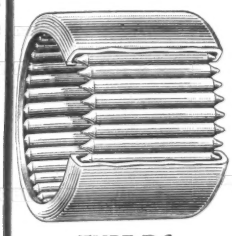


reachable inside surfaces or in tight places. Of corrosion-resistant aluminum alloy, the countersunk head Rivnut is available in three different head shapes and the flat head type is only the one shape. Each of these is made in three nominal sizes, Nos. 6-32, 8-32, and 10-32, and in six grip ranges. The nuts can be furnished with open or closed ends, and with or without keys under the head in all styles with the exception of the thin head countersunk type.

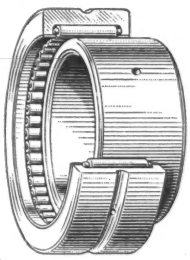
Aviation Sealing Tapes

THREE new sealing tapes—Chromseal, Fabseal and Stratoseal—are contributing to the speed of airplane production, according to the producer, Pittsburgh Plate Glass Co., Grant building, Pittsburgh. Chromseal, a solid ribbon of compound with no fabric in its composition, is suitable for a gasket material between riveted or bolted surfaces of integral fuel tanks, droppable fuel and oil reservoir tanks, as well as a sealant for plastic enclosures and glass cockpit framing. For molding to conform to any angle, curve or contour, the material also is highly resistant to gasoline, oil and water. It is available in three thicknesses: .015, .025 and .062-inch, and in widths from ½ to 24 inches in standard 50-foot rolls. Fabseal, de-

Yes, these are ALL Needle Bearings . . .



TYPE DC



TYPE NCS

DESIGNED FOR TODAY'S NEEDS AND TOMORROW'S TRENDS—THEY OFFER A UNIQUE COMBINATION OF ADVANTAGES

You may not have realized how many *different* types of Needle Bearings have been developed since the first Torrington Needle Bearing was introduced.

Some of them are illustrated here.

Common Advantages

All of them employ the basic principle of a full complement of small diameter needle rollers within a single, compact retaining raceway. And all of them offer the characteristic advantages of the original Torrington Needle Bearing:

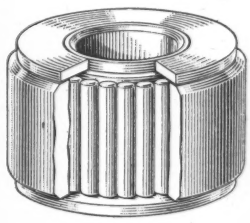
1. Small size, light weight and compact design
2. High radial load capacity and elimination of stress concentration
3. Unit construction which facilitates handling and installation
4. Efficient lubrication; freedom from maintenance attention
5. Low cost

For Special Requirements

Each of the "newer" types is designed for a particular task . . . a particular set of conditions.

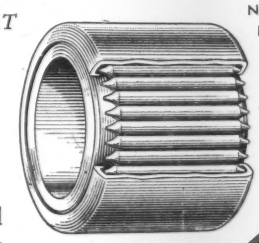
Some of them were so well established even before the war as to be almost universally used for certain applications. For example, the NCS Type Needle Bearing, of rugged construction, designed for heavy service, and available in standard sizes to fit an inner race of from ⅝" O.D. to 5½" O.D., is widely employed in equipment for the oil industry where service conditions are severe and rough "handling" the rule.

Others are the result of wartime demands for greater efficiency in speeding production lines and stepping up performance records. The AT Type Needle Bearing, for instance, has a heavy, through hardened outer race designed to give maximum capacity obtainable from the rollers



TYPE AT

used. It has found wide application in the aircraft construction where it is used with standard AN bolts and is designed to have a static non-Brinell capacity equal to the single shear strength of the bolt. Standard sizes in the AT Type range from 0.1900 to 1.0000" to fit on bolts No. 3 to 16.



DC (INNER RACE)

For Postwar Designs

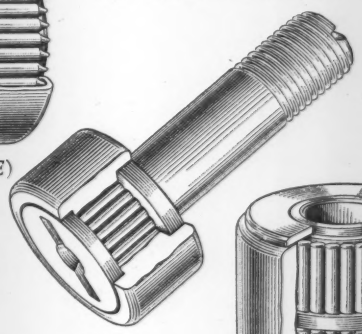
Where the efficiency of anti-friction operation is desired, and space, weight and cost are vitally important considerations—as they will be in designing to meet postwar trends—Needle Bearings provide the answer!

With the development of a complete line of all types, The Torrington Company offers the product designer and engineer a selection to meet virtually *any radial load requirement*. The experience of Torrington engineers is available to aid in design and application of Needle Bearings to *your* particular job. A copy of our current Catalog No. 109 will give you an outline of the types, sizes and capacities currently available for essential needs. And if our engineering staff can assist in selecting the right type for a particular job, write, outlining your need.

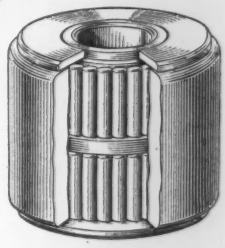
THE TORRINGTON COMPANY

Established 1866 • Torrington, Conn. • South Bend 21, Ind.
"Makers of Needle Bearings and Needle Bearing Rollers"

New York Boston Philadelphia
Detroit Cleveland Seattle
San Francisco Los Angeles
Chicago Toronto London, England



TYPE RC



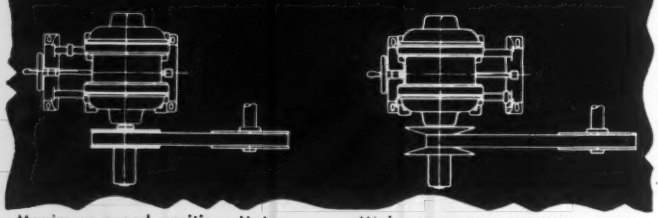
TYPE FDT

TORRINGTON
NEEDLE BEARINGS

Do Machines You Design Have Their HANDS TIED by FIXED SPEED?

IDEAL VARIABLE SPEED

Changes Speed at Will WITHOUT STOPPING



Maximum speed position. Motor close to driven sheave. V-Belt at largest pitch diameter.

Minimum speed position. Motor away from the driven sheave. Pulley open to smallest pitch diameter.

WHY build machines with "Tied Hands" when you can design them with a wide "range of speeds". Not just a few step speeds—but any range of speeds up to 3 to 1 ratio to meet the changing conditions of different jobs—different operators—different materials.

Easy to equip with IDEAL Variable Speed and inexpensive. Usually requires no change in basic design.

Available in V-Belt and Wide V-Belt Types.

FREE . . . .

TRANSMISSION HANDBOOK

52 pages filled with new Transmission ideas—detailed data on Variable Speed Control Equipment—technical engineering information—applications—how installed. Send for your copy today.

IDEAL *Sycamore*

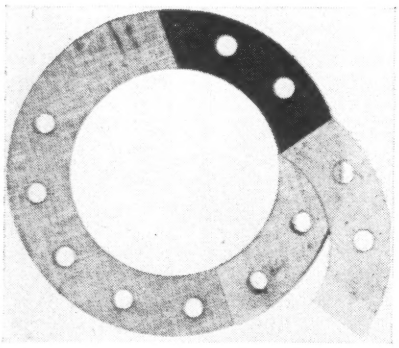
★ IDEAL COMMUTATOR DRESSER CO ★

1059 Park Avenue — Sycamore, Illinois

Sales Offices in All Principal Cities

In Canada: Irving Smith Ltd., Montreal, Quebec

signed for use as a gasket in the construction of flying boat hulls, gas and oil tanks where internal or external pressures are encountered under constant vibration or sudden impact, is an impregnated fabric with an interleaf separating the fabric layers. Also water, gasoline and oilproof, this type may be applied to any metal or wood section. After application the interleaf is removed, exposing upper surface of tape which is ready to receive



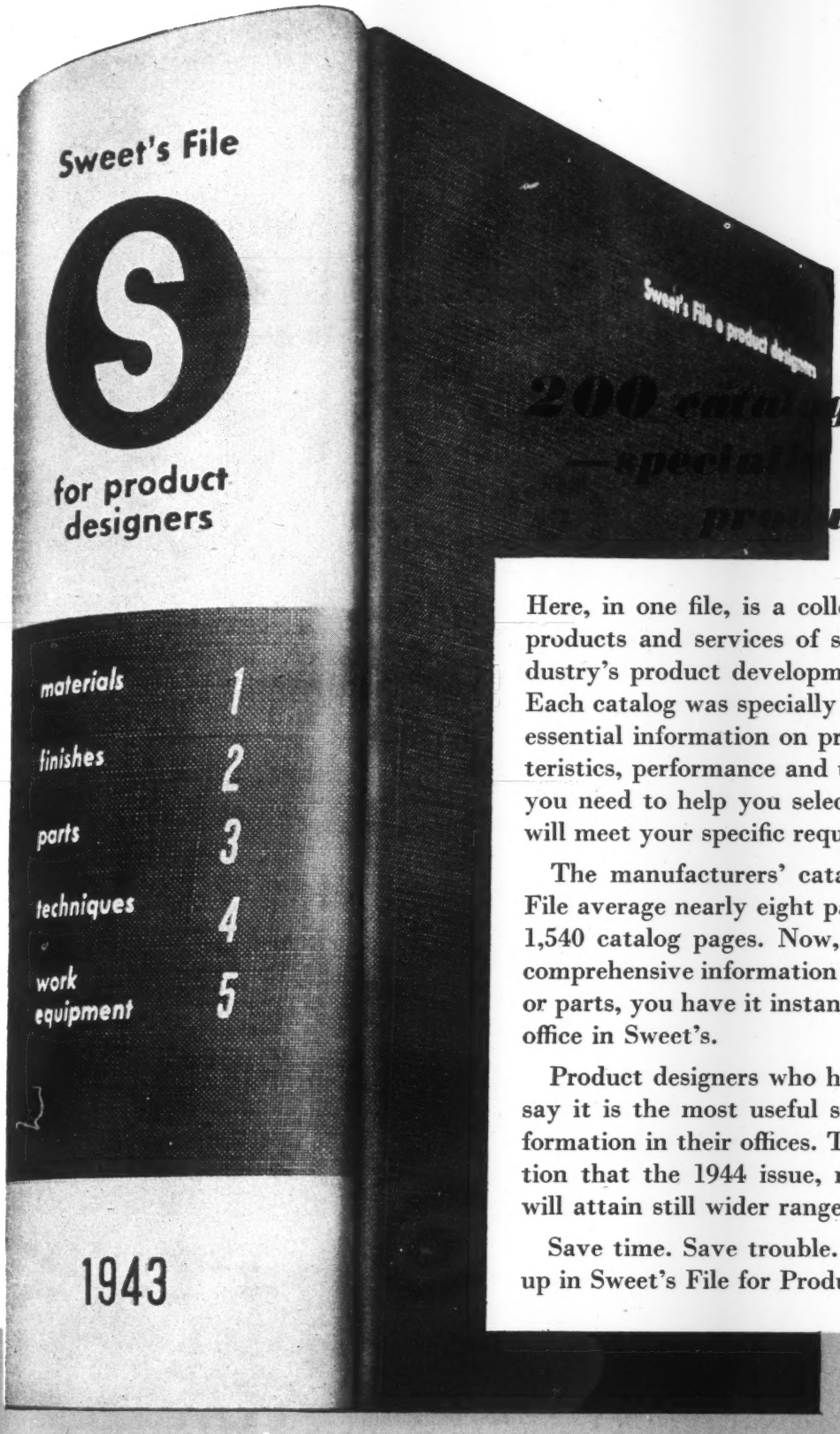
another riveted or bolted section. It is .010-inch thick when compressed, and can be doubled depending on application. Thickness is .015-inch and width ½ to 16 inches, in standard 50-foot rolls. The third tape, Stratoseal, was developed to meet a demand for a sealant in pressurized cabins for high altitude flying. It remains flexible at —70 degrees Fahr. and resists temperatures to 150 degrees Fahr. This tape is also available in thicknesses of .01, .015 and .025-inch, in widths from ½ to 24 inches, and in 50-foot rolls.

New Zinc Anodizing Method

APPLICABLE to zinc plated on any metal, and in some cases to zinc-base die castings a method for anodizing zinc announced by United Chromium Inc., 51 East Forty-second street, New York 17, increases the rust-resistance of zinc-coated steel parts and retards the formation of white zinc corrosion. To many parts now being plated or black finished this treatment will give an improved appearance as well as longer service life. According to the Army-Navy salt spray test AN-QQ-S-91, the new Anozinc baths have held up for more than 200 hours. The finish is available in two types: A dark, semilustrous black and a brassy, slightly iridescent yellow.

Photoelectric Flame Control

FOR providing instantaneous fuel cut-off in any pressure-fed burner in the event of flame failure, a photoelectric system known as Fireye Type F28C is announced by Combustion Control Corp., Cambridge, Mass. Capable of monitoring flame of any intensity, the system is applicable to oil, gas or pulverized coal burners and operates entirely from direct observation of the flame rather than wholly or partly from temperature or electrical conductivity. This flame failure safeguard is used with manually ignited burners to cut off fuel and sound an alarm;



200 catalogs in one file —specially designed for product designers

Here, in one file, is a collection of catalogs on products and services of special interest to industry's product development and design men. Each catalog was specially designed to give you essential information on product forms, characteristics, performance and use—the information you need to help you select the product which will meet your specific requirements.

The manufacturers' catalogs in this Sweet's File average nearly eight pages each—a total of 1,540 catalog pages. Now, whenever you need comprehensive information on materials, finishes or parts, you have it instantly accessible in your office in Sweet's.

Product designers who have received this file say it is the most useful source of product information in their offices. There is every indication that the 1944 issue, now being compiled, will attain still wider range and usefulness.

Save time. Save trouble. Save delay. Look it up in Sweet's File for Product Designers.

A new 1944 file is now being compiled

Sweet's Catalog Service
Division of F. W. Dodge Corporation
119 West 40th Street, New York 18, N. Y.

These Are Our Boys!

Official U. S. Signal Corps Photo

THEY'VE got a tough job ahead of them as they step out on this enemy beach. But we know they'll give 'em the works. And we'll give everything we've got back home, too—we'll work overtime without kicking, we'll go easy on gas and tires . . . and we'll buy War Bonds with every extra dollar.

They are risking their lives . . . and we *must* do *our* part.

THE GARLOCK PACKING COMPANY, PALMYRA, N. Y.

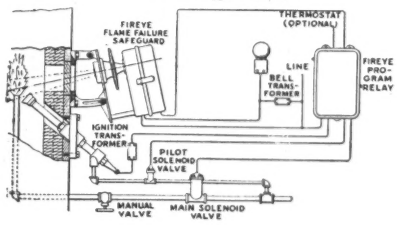
Manufacturers of GARLOCK Packings, Gaskets and KLOZURE Oil Seals

In Canada: The Garlock Packing Company of Canada Ltd., Montreal, Que.

GARLOCK

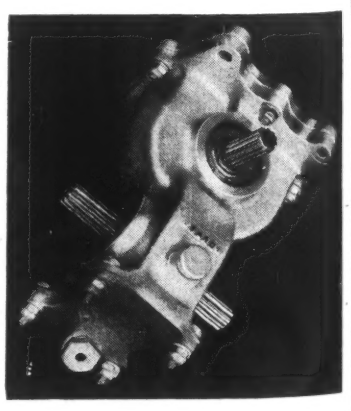
or, when the burner is automatically fired, with program relay Type R25, to program fuel pump and valve operation, intermittent ignition system, purging period, and recycling. It is mounted directly on the furnace wall from where it watches the flame through a window in

FIREYE Type F28C



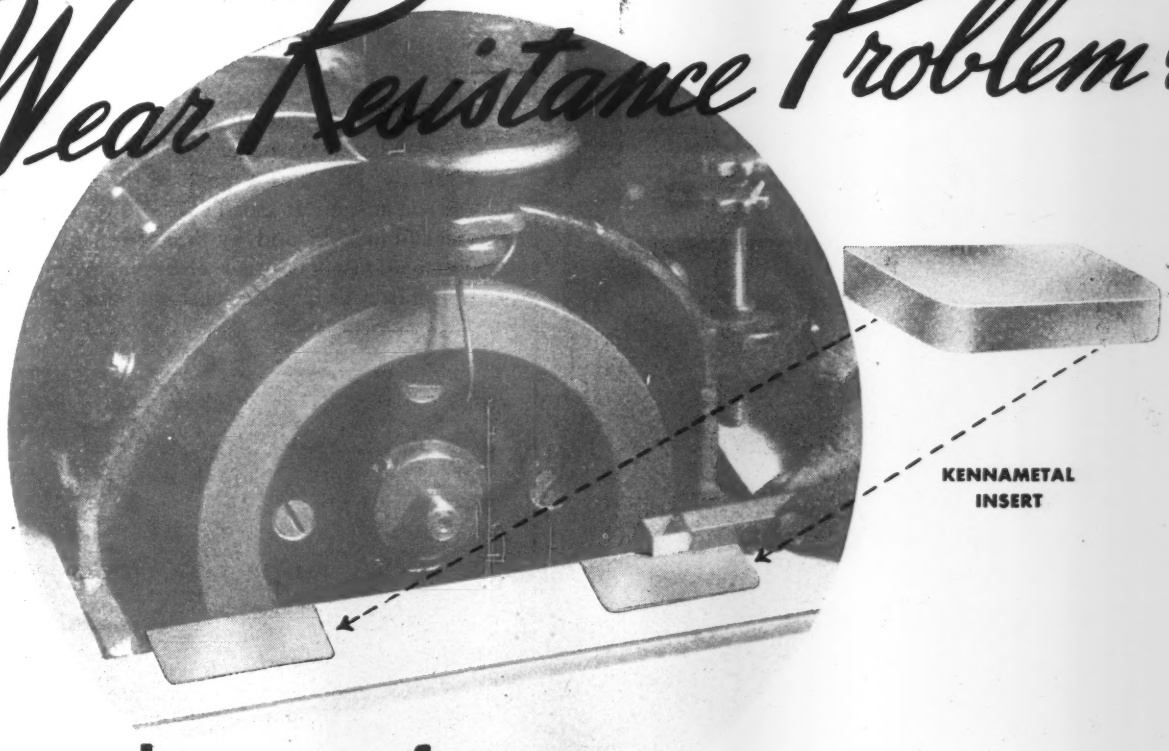
the wall of the fire chamber. Once the lens of the optical system has been aligned, the field of vision of the electric eye is limited to the flame itself and extraneous light is rejected. While the electric eye sees flame, fuel is fed to the burner. When flame fails, or any condition within the electronic control arises which impairs operation, the fuel supply is cut off until proper combustion conditions are restored. Because the system is actuated by presence or absence of flame, it operates immediately and eliminates the explosion hazard present when a few seconds elapse before fuel cutoff.

Lightweight Transmission Unit



TO FILL requirements for small, lightweight power transmission units Vard Inc., 2961 East Colorado boulevard, Pasadena 8, Calif. is making a light-weight gear box, simple in construction. It was first designed for use on aircraft as a junction box for emergency operation of a lineshaft, and now it has been found useful in application on various types of machines. Designed for horizontal mounting, the drive may be connected either parallel or at right angles. Distance between the centers of shafts is 2½ inches. Attachment shafts are supplied with a 24-48 pitch, 11-tooth

Do you have a *Wear Resistance Problem?*



Here is one of many *Solved with* KENNAMETAL

The steel tool-rest on this grinding machine required resurfacing *once a month* because movement of the tool back and forth wore depressions that interfered with accurate grinding—friction between the rest and tool shank, in combination with abrasive action of wheel grit, did the damage.

Since Kennametal blanks were inserted as shown, maintenance troubles have been minimized—wear is so much less that reconditioning the surface is required only after a period of *five months*.

Kennametal as used here is the same hard, durable intermetallic compound, containing tungsten-titanium carbide, that has been distinctively successful in extending the effective service life of turning, boring, and facing tools. Grade K4H, having a hardness of 80.6 on the Rockwell C scale, is the most wear-resistant. Contributing further to increased life of wearing parts is the lower coefficient of friction between Kennametal and steel as compared to that between steel and steel.

Perhaps there are elements in some of your machines that are subjected to excessive wear. If so, Kennametal will relieve your trouble. In many cases, standard blanks can be used. For individual requirements, special inserts can be provided at moderate cost.

Kennametal engineers will welcome the opportunity to help solve your wear resistance problems. Standard and formed blanks are discussed in detail in the new Kennametal Catalog 43-C. Write for your copy.

KENNAMETAL

Trade Mark Reg. U. S. Pat. Off.

KENNAMETAL *Inc.*
146 LLOYD AVE.
LATROBE, PENNA.

SUPERIOR CEMENTED CARBIDES

A Mobile Service...

FOR ANY GUN — PISTOL TO HOWITZER

"Keep 'em Firing"—no matter where they are. That's the slogan. Repair crews, with their mobile workshops, service all types of guns, from pistols to howitzers. Generating units, powered by gasoline engines, charge batteries and operate electric drills and other modern tools. This is typical of the multitude of vital jobs—both standard and special—for hundreds of thousands of rugged, dependable Briggs & Stratton engines "in the service."

TO those manufacturers now designing and experimenting with machines, tools, or equipment to be powered by portable gasoline engines, we offer the services and long experience of Briggs & Stratton's engineering and development staffs, without any expense or any obligation.

Their assistance and counsel may save you weeks of time and many headaches, and effect material economies and greater efficiency.

The reputation of Briggs & Stratton is world wide in the gasoline engine field. Thousands of dealers and millions of owners and users know that —

"It's powered right—when it's powered by Briggs & Stratton."

BRIGGS & STRATTON CORP.
MILWAUKEE 1, WIS., U.S.A.

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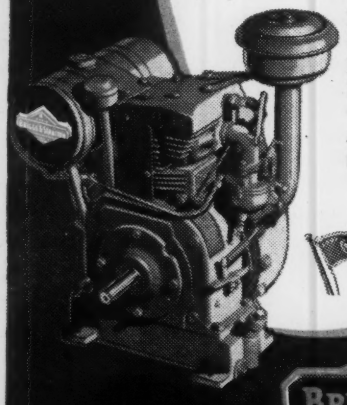
Back the Attack with More War Bonds

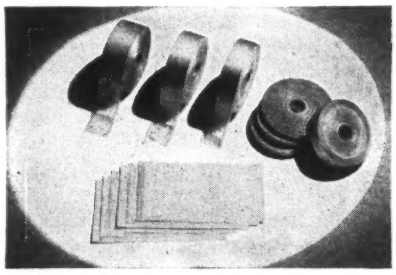


4 CYCLE
BRIGGS & STRATTON
GASOLINE ENGINES

involute spline with a 30-degree pressure angle and a pitch diameter of .4583. It is designed for a maximum torque of 900 inch-pounds.

Synthetic Dielectric Material

KNOWN as Lectrofilm, a new synthetic dielectric material has been developed by General Electric Co., Schenectady, N. Y., as a result of the growing shortage of high-grade mica. It can best be applied to most radio-frequency-blocking and by-pass, fixed capacitors used in communications and other electronic equipment. Available in both rolls and sheets, Lectrofilm can be used with



little change in equipment or method of manufacture, and its strength and flexibility make it well-suited to automatic methods of manufacture. Control in production of this material, together with its chemical stability, assures uniform properties and freedom from defects. Little grading or sorting before being placed into a capacitor production line is required. The material is being made available to manufacturers making capacitors for the armed forces.

High-Power Electronic Condensers

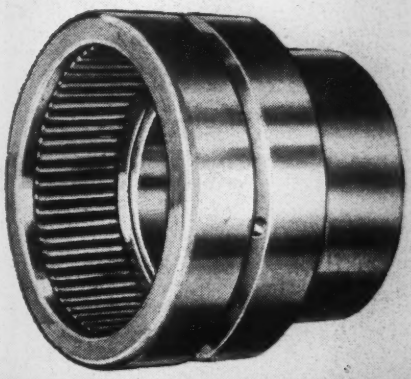
HEAVY-DUTY variable air condensers for electronic heating applications are being offered by Barker & Williamson, 235 Fairfield avenue, Upper Darby, Pa. Of sturdy unconventional design offering many advantages for heavy-duty applications, the Type CX variable condensers feature perfect electrical design symmetry and built-in neutralization coupled with mechanical durability. The construction also lends itself to built-in mounting of standard inductors in such a way that lead lengths and resulting lead inductance are reduced to a minimum. The condensers are available in any required capacity for electronic heating use up to 5 kilowatts, 12,500 volts.

Engineering Dept. Equipment

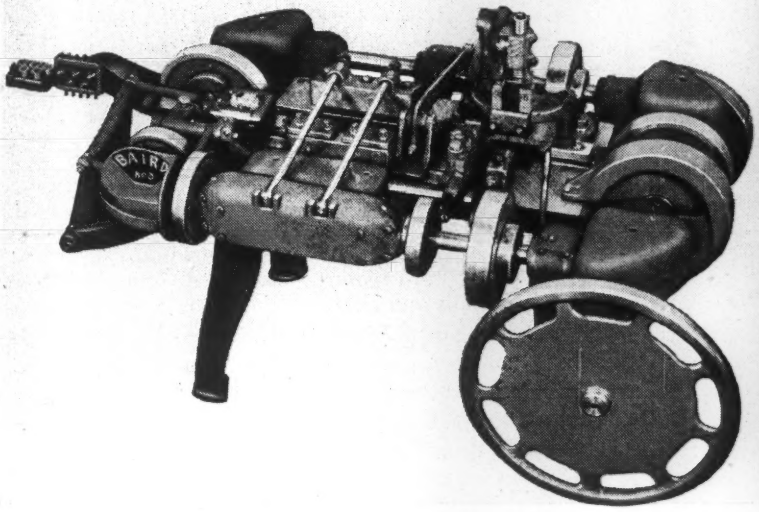
Three Slide Rules Available

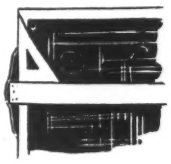
THREE new slide rules have been announced by The Frederick Post Co., Box 803, Chicago 90—one for the professional draftsman, one for the apprentice draftsman and a one-hand five-inch pocket slide rule. All three contain the scales A, B, C, D, CI, K, S, L and T, and are celluloid-faced with the exception of the apprentice rule which has a painted face. Produced as an emergency

IN BAIRD FORMING MACHINES CAMS RUN FAST AND SMOOTH ON



ORANGE ROLLER BUSHINGS





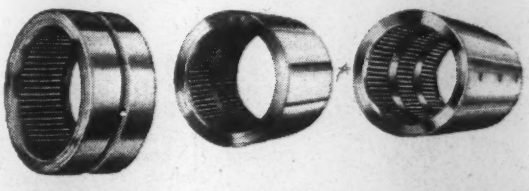
Have you a product on the drafting board requiring protection of rotating or oscillating parts against friction and wear? Orange Roller Bushings give you the solution—whether to carry heavy loads in limited space . . . to provide even, quiet, high speed running . . . to maintain smooth, precision operation —or to add longer life to hard-working parts.

Orange Roller Bushings are meeting just such requirements in all types of equipment, with remarkable success. The high load carrying capacity and exceptionally smooth running of Orange Roller Bushings result from their basic design and extreme standards of precision manufacture. Full details are contained in our Engineering Data Book, which shows range of sizes and types, plus installation suggestions. Send coupon for your copy.

CONSULT OUR ENGINEERS ON ANY BEARING APPLICATION

ORANGE ROLLER BEARING CO., INC.
ORANGE • NEW JERSEY

Baird Forming Machines are ingeniously designed to produce articles of wire or ribbon metal, in every conceivable shape and size. Among the many features of these Baird production machines is their speedy, smooth operation — to which Orange Roller Bushings in the cam rolls make a valuable contribution.



Mail Coupon for Engineering Data

Orange Roller Bearing Co., Inc., MD
Orange, N. J.

Please send me your Roller Bushing Data Book

Name ..... Title .....

Company .....

Address .....

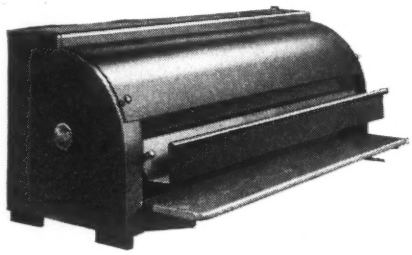
City ..... State .....

WRINKLE
A PROVEN WARTIME FINISH
GLARE PROOF—
Wrinkle being a relatively dull finish does not give away position to the enemy.
HEAT, COLD AND MOISTURE RESISTANT—
The Elements do not affect substantially the toughness of Wrinkle.
SURFACE PROTECTION—
Being a hard finish, Wrinkle protects any surface from scuffing and hard use effects.
ONE COAT DOES THE JOB
Wrinkle being a one-coat-finish, eliminates costly, time-consuming finishing operations.
Billy Wrinkle Says
"What Wrinkle will do for your product is best explained in 'New Wrinkles in Finishing'. Write for your copy today."
NEW WRINKLE INC.
314 W. FIRST ST. · DAYTON 2, OHIO
"WRINKLE", "NEW WRINKLE", AND "BILLY WRINKLE" ARE REGISTERED TRADE-MARKS OF NEW WRINKLE, INC.

measure, they are well constructed, accurate slide rules and are equipped with a case and instruction sheet.

Whiteprint Developing Machine

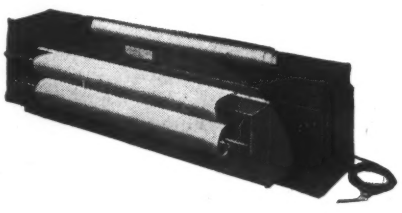
KNOWN as Model 700, a new table model for dry developing whiteprint reproductions of engineering drawings and tracings has been made available by The C. F. Pease Co., 2601 West Irving Park road, Chicago. A developer only, this machine has two production speeds, four and eight feet per minute. It is easily operated and can be used in conjunction with any blueprinting or di-



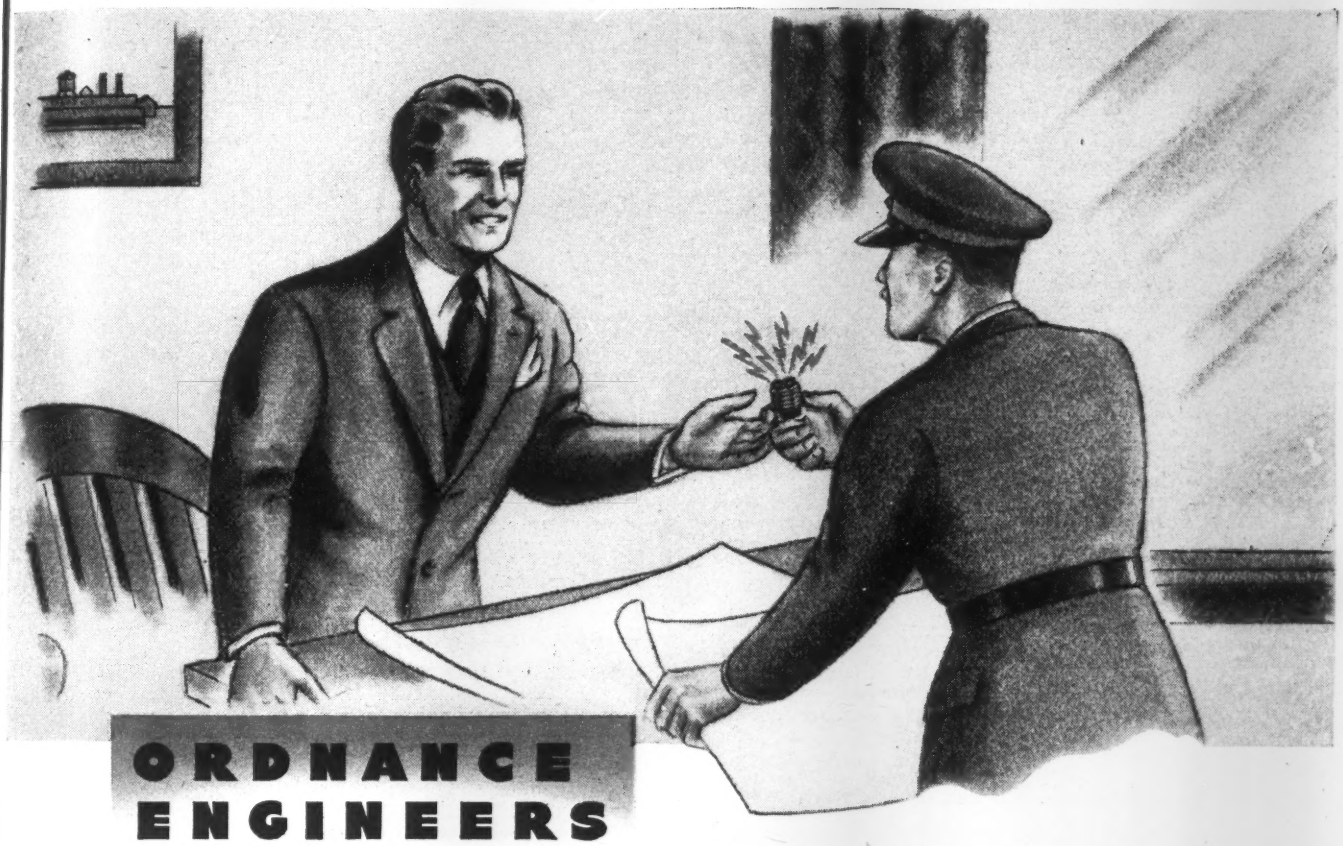
rect-process printing machine using any dry direct-process paper. Especially suitable for operation with the company's models Nos. 77 and 66 high-pressure quartz tube printers, the new developer is of sturdy, lightweight, welded steel construction, featuring easy accessibility through quickly removable sheet metal guards. It is made in two sizes, 42 and 54 inches.

Table-Type Continuous Printers

COMPACT, easily portable, table-top continuous printers have been announced by Peck & Harvey, 4327 Addison street, Chicago. Available in two models B-1 and B-2, they produce clear, sharp blueprints or direct process black and white prints to 44 inches wide in any lengths at a speed up to 42 inches per minute. No special wiring is required; they can be simply plugged into any standard electric outlet. Any drawing or trac-



ing, or printed matter to 44 inches in width, or any combination (as many as five 8½ x 11-inch sheets) may be fed into the machine at one time, and it will print any length continuously, without side travel, blurring, or wrinkling. Mercury vapor tube lamps are mounted horizontally to give uniform light intensity overall. Super-clear, hand-polished contact glass and sliding contact insure clear, clean overall exposure. A ball-bearing equipped variable-speed drive provides a wide range of speeds. Overall dimensions of both models are: 16 x 16 x 63 inches.



ORDNANCE ENGINEERS *have an Idea for* DESIGNERS OF POST-WAR PRODUCTS!

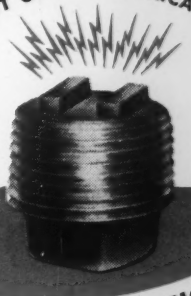
A new method of protecting bearings and gears against excessive wear is now available for use in postwar products. It simply involves replacing ordinary drain plugs with Lisle Magnetic Plugs. On far-flung battlefronts Lisle Plugs have more than lived up to the expectations of Ordnance Engineers by cutting down bearing wear and maintenance problems in many types of equipment.

A powerful magnet in the Lisle Plug attracts and holds any iron or steel particles which form in the lubricant as a result of ordinary wear. Removal of this abrasive metal eliminates one of the most common causes of premature bearing failure. No change of design is necessary—just use the Lisle Plug in place of an ordinary drain plug.

FREE! **Engineers are invited to send for sample Lisle Magnetic Plugs for experimental use. See for yourself how Lisle Plugs pull abrasive metal out of the lubricant.**

Lisle Corporation, Box 1003, Clarinda, Iowa

PULLS ABRASIVE METAL OUT OF THE LUBRICANT



ARMY NAVY E

Lisle Magnetic DRAIN PLUGS

FITS RIGHT INTO YOUR POST-WAR PLANS

"Oomph" DRAFTING

NO-INK Drawing Board **TOP**

Adopted as Standard By Major Industries

RE-SURFACE
Worn Boards. Modernize New Boards.

PRECISION-IZE
Pencil Drawings for Perfect Prints.

RELIEVE
Shortages of Men and Materials.

SPEED
Production, Yet Cut Costs.

Resilient drawing surface produces a sharp, opaque stroke in the drawing —results in perfect prints—makes inking unnecessary. The most perfect, most delightful surface to work on.

10 Years More Use From Old or Discarded Boards

Users are reordering in quantity. Over 25,000 NO-INK Drawing Board Tops already in use, saving man-hours, speeding production, renewing discarded boards, modernizing new boards. Costs so little.

We cut Tops to exact board size, no matter how large or how small. Attached by anybody in 10 minutes, ready for immediate use. Economize, modernize your drafting procedure. Write for catalog, prices and trial offer.

Est. 1911. Over 30 Years of Guaranteed Customer Satisfaction

W. H. LONG COMPANY, 425 NO. CLARK ST., CHICAGO 10, ILL.

24-HR-A-DAY Operation

As one shift relieves another Gusher Coolant Pumps are ready to go . . . and keep on going. Simple design—fewer parts to wear—makes Gusher Pumps "steady performers." You get a copious flow of coolant when you want it and where you want it. There's a Gusher model for your requirements. Write.

GUSHER COOLANT PUMPS

MODEL 9040 — Available in any current characteristics, including 25 cycle, 1, 2, or 3 phase. Totally enclosed ¼ h.p. motor.

THE RUTHMAN MACHINERY CO.
1811 READING ROAD CINCINNATI, OHIO
LARGEST EXCLUSIVE BUILDERS OF COOLANT PUMPS

MEN OF MACHINES

A DESIGNER who has "designed everything from baby carriages to refrigerators"—Ralph E. Kruck has been appointed manager of the product design department of the Westinghouse Electric Appliance Division. Since 1931 Mr. Kruck has been an industrial designer for the company, and in this new post will have the job of "appearance-designing" ranges, laundry machines and all other appliances the company will build after the war. With headquarters in Mansfield, O., Mr. Kruck will work closely with the engineering, sales and advertising departments. Prior to his appointment he was a member of the company's engineering department at East Springfield, Mass., designing household and commercial refrigeration and air conditioning equipment. Two years ago his designs earned him the company's order of merit in recognition for "distinguished service, particularly for his creative work in the field of industrial design; for his ability to create designs adaptable to practical manufacture, and for his creation of new standards of beauty in the field of household refrigeration."

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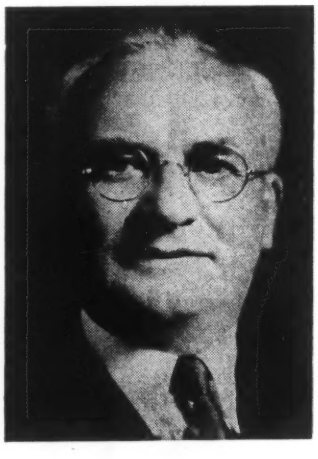


AT ITS annual meeting the American Welding Society elected as president David Arnott, who has been active in the society since its early days, particularly in its technical activities relating to ship welding. Connected with the American Bureau of Shipping, Mr. Arnott has delivered a number of papers before various sections of the society and is author of an important chapter of the Welding Handbook. He has been a strong supporter of research activities and at the present time is chairman of the society's committee on welding and ma-

SIMPLICITY OF APPLICATION

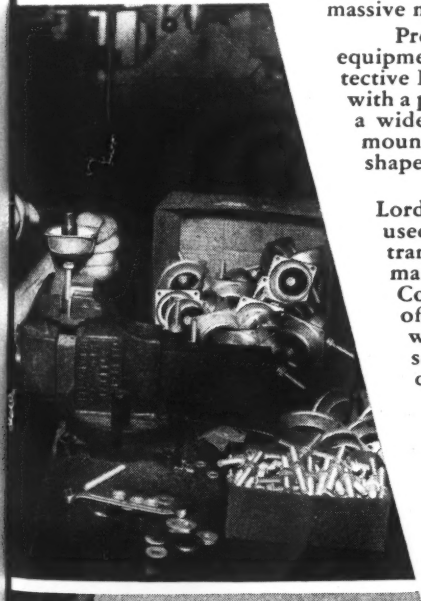
. . . and High Degree of Vibration Isolation are Basic Features of ➡ ➡ ➡

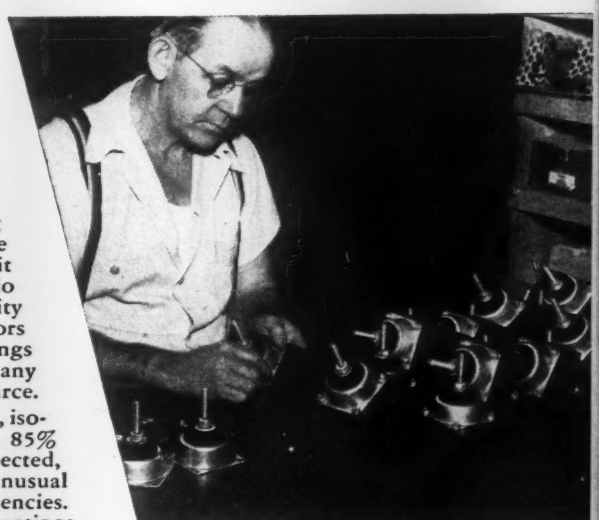
LORD
BONDED RUBBER
Shear Type
MOUNTINGS

MILLIONS of Lord Mountings are in use today, providing protection against the harmful effects of shock and vibration on all types of industrial, military, and naval equipment, from light, delicate instruments to heavy, massive machinery.

Providing such protection in modern equipment designs may well be termed "Protective Engineering". To engineers confronted with a problem of vibration control, Lord offers a wide variety of bonded rubber, shear type mountings from the standpoint of function, size, shape, load ratings, and methods of application.

The accompanying photographs show Lord Plate Form Holder Type Mountings being used to float electric generators within the transmitter housing of a marine radio unit manufactured by Federal Telephone and Radio Corporation, at Newark, New Jersey. Simplicity of application is well illustrated. The generators weigh 110 pounds each, and the mountings serve to isolate component equipment from any disturbing forces emanating from this source.

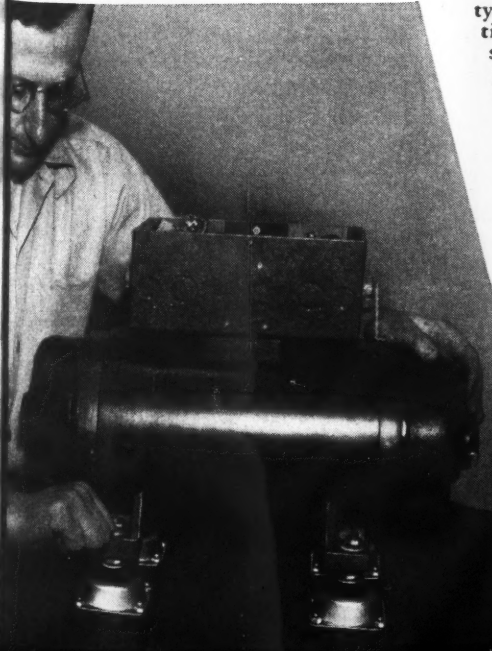




Through proper mounting selection, isolation efficiencies ranging from 75% to 85% reduction of disturbing forces may be expected, although reductions up to 97% are not unusual in equipment operating at very high frequencies. The remarkable efficiency of Lord Mountings is due to the accuracy, precision, and uniform quality of manufacture.

Lord Mountings are made in two main types, Plate Form and Tube Form, with variations to suit special conditions. Load ratings of standard sizes range from a few ounces to 1500 pounds. They absorb shock, control vibration, and minimize all noise transmitted through solid conduction.

For complete information covering all Lord Mountings, as well as engineering discussion on vibration control, write for Bulletins 103 and 104, or call in a Lord Vibration Engineer for consultation on your vibration problems. There is no obligation.



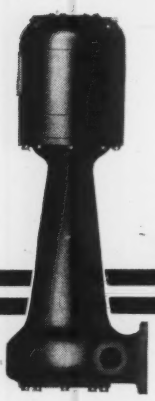
Back The Attack—Buy War Bonds

IT TAKES RUBBER *In Shear* TO ABSORB VIBRATION

LORD MANUFACTURING COMPANY
ERIE, PENNSYLVANIA

SALES REPRESENTATIVES
NEW YORK - - 280 MADISON AVE.
CHICAGO - 520 N. MICHIGAN AVE.
DETROIT - - 7310 WOODWARD AVE.
BURBANK, CAL. - 245 E. OLIVE AVE.

Originators of Shear Type Bonded Rubber Mountings



INDUSTRY SAYS "TOPS"

MANY FEATURES COMBINE TO MAKE THIS

PIONEER

MODEL VBD

AN OUTSTANDING PUMP

Provided with three pipe tapped outlets (right, left, and back into coolant sump), this Pioneer Pump model offers you great flexibility. It reduces your stock inventory; you don't have to carry a variety of pump models to satisfy the need for different outlets. One model is all you require.

This model will pump liquids usually considered difficult to handle, such as abrasives, etc.

The unit is designed to assure safe operation of motor; liquid cannot affect it.

These are a few of the high spots that distinguish the Model VBD—real efficiency from top to bottom of its streamlined body.

Pioneer Pump & Manufacturing Co.
19652 John R Street, Detroit 3, Mich.

PIONEER Pumps

HIGH EFFICIENCY • LOW POWER CONSUMPTION
GREATER VOLUME AND LESS MAINTENANCE

rine construction. Mr. Arnott also served on the executive committee. Born in Glasgow, Scotland, in 1878, he is a graduate of the Royal Technical College. He received his apprentice training as a ship welder and later served as a surveyor in Glasgow. He also was principal surveyor for Canada from 1917-1918, stationed at Toronto. Later, from 1918-1925, he became deputy chief surveyor of American Bureau of Shipping, New York, and then chief surveyor of the American Bureau of Shipping, the position he now holds. To these duties were added those of vice president of the bureau in 1938, which position he also now fulfills.

♦

CHARLES SARDOU JR., formerly chief draftsman for Kinner Motors Inc., and standards and patent engineer of Vultee, has recently been promoted to chief draftsman of Consolidated Vultee Engineering and Development Division, Downey, Calif.

♦

FELIX C. REICHLIN has been made design engineer for AiResearch Mfg. Co., Los Angeles. He had been connected with Kinner Motors Inc., Glendale, Calif., as engine designer.

♦

ROBERT T. GOFFIN, process engineer for Sterling Engine Co., Buffalo, N. Y., has joined Sperry Gyroscope Co. Inc., Great Neck, L. I., N. Y., as senior methods engineer.

♦

EDWIN A. DROEGEMUELLER has joined Pratt & Whitney Aircraft, East Hartford, Conn., as assistant project engineer. He formerly was connected with Standard Oil Co. (Ind.) Engine Laboratory, Whiting, Ind., as research engineer.

♦

DWIGHT AUSTIN has recently resigned as new development engineer of Yellow Truck & Coach Co., Pontiac, Mich., to organize a new company Dwight Austin & Associates, consulting engineers, with headquarters in Kent, O.

♦

ALEX L. HAYNES has joined the Aircraft Development Section, General Motors Corp., Detroit, as design engineer. He was connected in a similar capacity with Stinson Aircraft division, Consolidated-Vultee Aircraft Corp.

♦

PAUL E. HOVGARD has resigned as chief engineer, Glenn L. Martin Co., to join Curtiss-Wright Corp., Airplane division, Buffalo, N. Y., as technical assistant to the director of engineering.

♦

T. F. BRUDNELL has become connected with Caterpillar Military Engine Co., Decatur, Ill., as assistant design engineer. Previously he had been with Witte Engine Works, Kansas City, Mo., as chief draftsman.

♦

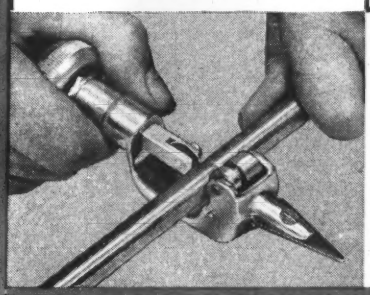
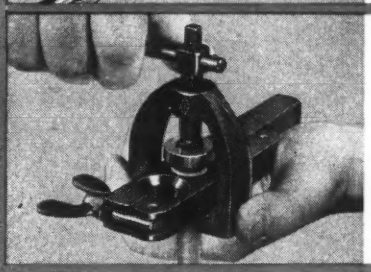
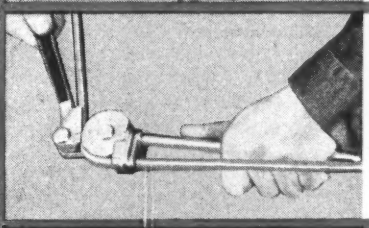
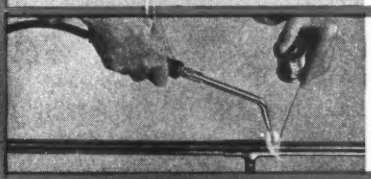
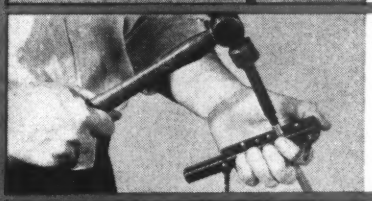
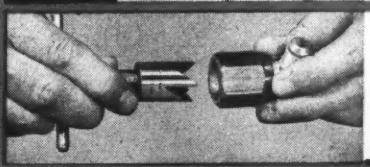
DR. R. P. DINSMORE was recently elected vice president in charge of research and development of the Goodyear Tire & Rubber Co.

♦

EDGAR C. BAIN, past president of the American Society

Helping industry work with tubing quickly—easily—efficiently

IMPERIAL *Tube-Working* TOOLS

	Tool in Use	Size Tubing Serviced	Description of Tool	Cat. No.
CUTTING		3/16" to 3/4"	Roller type. Has special groove for cutting off flares. Illustration at left shows this tool in use.	174-F
		1/8" to 3/4"	Tubing rests on "V" instead of rollers	94-F
		7/16" to 1 1/8"	Wide range, roller type with flare removal groove.	212-F
		1/8" to 3/4"	Small, inexpensive, pocket size cutter.	127-F
		1/8" to 2"	Sawing vise.	184-F
		1 1/2" to 4"	Sawing vise.	185-F
FLARING		3/16" to 3/4"	Wide range type	175-F
		3/16" to 1/2"	For smaller range of diameters	93-F
		1/4" to 5/8"	Same as 93-F except size range	95-F
		3/16" to 1/2"	Has quick slip-on yoke	193-F
		3/4" to 1"	For larger sizes	103-F
		3/16" to 1/2"	For double-flaring steel tubing. Also general flaring. Illustration at left shows this tool in use.	93-FB
BENDING		1/4" to 5/8"	Spring bender set—outside type	101-F
		3/16" to 3/4"	Open-side bender. Positions anywhere. Calibrated in degrees. Each bender takes one size tubing. Illustration at left shows this tool in use.	364-F
		3/8" to 3/4"	Heavy duty bender outfit. Takes four sizes of tubing	360-F
SOLDERING		For use on all soldering work	Outfit includes torch, 4 tips, soldering iron, hose, and tank connections. Illustration at left shows this tool in use.	32
SWEDGING		1/4", 3/8", 1/2", 5/8"	For joining two pieces of copper tubing of the same size without the use of a fitting. Kit includes flaring bar, 4 swedging tools. Illustration at left shows tool in use.	195-S
		1/4" to 3/4"	Individual swedging tools—no bar	93-S
REFACING		1/4" to 5/8"	Refacing tool for refacing S.A.E. flare fittings which have become nicked or marred. Includes cutter, 5 adapters. Illustration at left shows this tool in use.	98-F

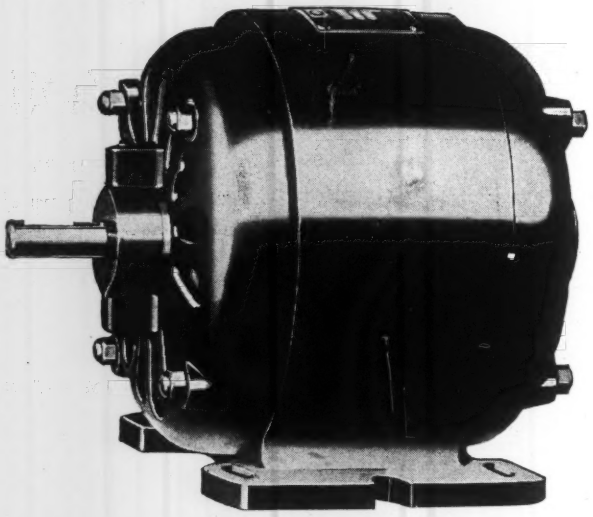
Imperial Tools are distributed by Industrial Supply Houses.

THE IMPERIAL BRASS MANUFACTURING CO.

513 So. Racine, Chicago 7, Illinois

OHIO

TORQUE MOTORS



Ohio Torque Motors are employed to release brakes and hold them open . . . operate gates and doors . . . turn valves . . . operate clutches . . . close and open switches . . . any job a solenoid or power cylinder can do.

They can be stalled for the length of time to suit the work cycle for which they are wound and not burn out, nor even over-heat.

Ohio Torque Motors are silent. Made for any power from 1 oz. ft. to 100 oz. ft., equal to 1-16 ft. lb. to 7½ ft. lbs., and to operate on one- two- or three-phase A.C., or up to 250 volts D.C.

What is your problem?

OHIO MOTORS INCLUDE

Split-phase Induction to 1/3 HP
Direct Current to 1 HP
Capacitor to 2 HP
Polyphase to 2 HP
Aircraft Motors
Shell Type to 7½ HP
Torque to 100 oz. ft.
Shaded Pole to 1/30 HP
Synchronous to 1/4 HP
A.C. to D.C. Motor Generators to 500 watts
High to Low Voltage D.C. Dynamotors up to 300 watts.

The OHIO ELECTRIC MANUFACTURING Co.
5906 Maurice Avenue Cleveland 4, Ohio

for Metals and assistant to the vice president of the United States Steel Corp., has been made vice president in charge of research and technology at Carnegie-Illinois Steel Corp.

♦

ROBERT C. CORLETT who for the past few months has been serving as executive vice president, has been made president of Goss Printing Press Co., Chicago.

♦

T. C. FOCKLER has been appointed a member of the American Standards association's subcommittee on ball and roller bearings and standardization of shafting. He is connected with Westinghouse Electric & Mfg. Co.

♦

E. F. LOWEKE, previously chief engineer of Hydraulic Brake Co., has been made hydraulic engineer of Hayes Industries Inc., Jackson, Mich.

♦

CHARLES E. MACDONALD is now design engineer for Vega Aircraft Corp., Burbank, Calif. He formerly had been acting project engineer, Kinner Motors Inc.

♦

H. E. SIMI, formerly chief engineer and manager of plant 10, C. L. Gougler Machine Co., and a past vice president of SAE, is now an engineer for Timken-Detroit Axle Co. For a number of years earlier, Mr. Simi had been chief engineer of Twin Coach Co.

♦

WILLIAM S. WATTS recently joined the Auto-Railer Division of Evans Products Co., Detroit, as chief engineer. Formerly he had been development engineer at Aircraft-Marine Products Inc., Elizabeth, N. J.

♦

GEORGE H. HUFFERD has been appointed director of research, Weatherhead Co., after resigning as development engineer of Houde Engineering division, Houdaille-Hershey Corp., Buffalo, N. Y.

♦

ROBERT L. SUTHERLAND is now an engineer in the research department of Aeronca Aircraft Corp., Midland, O. He had been connected with Buick Motor division, General Motors Corp., Melrose Park, Ill.

♦

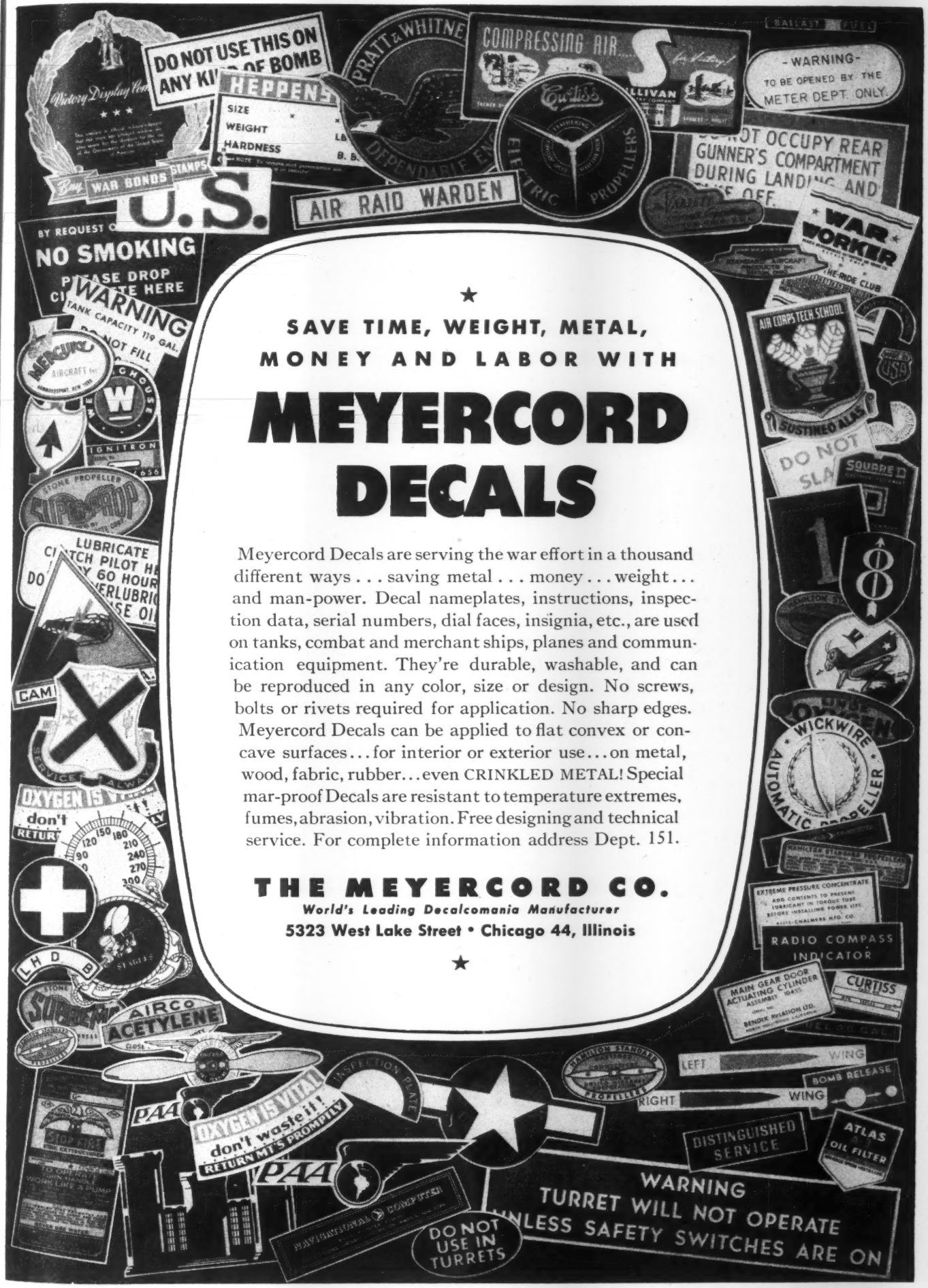
HANS RUTISHAUSER has become development engineer of Aerojet Engineering Corp., Pasadena, Calif. His former connection was with the Lycoming division, the Aviation Corp., Williamsport, Pa.

♦

VICTOR P. SHAFFER has been made engineer in charge of design for the Process division of H. K. Porter Co. Inc., Pittsburgh. In his new position he will also direct an expanded program of development and research. For the past ten years Mr. Shaffer has been associated with development work for Calco Chemical division of American Cyanamid Corp.

♦

ANTHONY NAIDEN, a design engineer, has joined the engineering department of the Westinghouse plant at East Springfield, Mass.



★

SAVE TIME, WEIGHT, METAL, MONEY AND LABOR WITH

MEYERCORD DECALS

Meyercord Decals are serving the war effort in a thousand different ways . . . saving metal . . . money . . . weight . . . and man-power. Decal nameplates, instructions, inspection data, serial numbers, dial faces, insignia, etc., are used on tanks, combat and merchant ships, planes and communication equipment. They're durable, washable, and can be reproduced in any color, size or design. No screws, bolts or rivets required for application. No sharp edges. Meyercord Decals can be applied to flat convex or concave surfaces . . . for interior or exterior use . . . on metal, wood, fabric, rubber . . . even CRINKLED METAL! Special mar-proof Decals are resistant to temperature extremes, fumes, abrasion, vibration. Free designing and technical service. For complete information address Dept. 151.

THE MEYERCORD CO.

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★

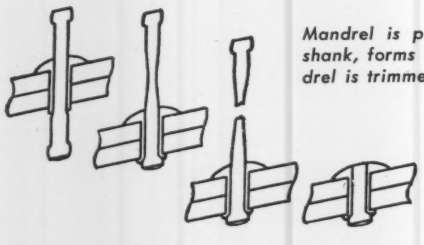
HOW TO HEAD A RIVET IN A TUBE

CHERRY BLIND RIVETS

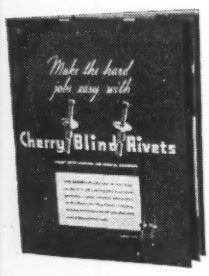
CHERRY BLIND RIVETS are ideal for riveting tubing to elbows, brackets or other tubing. Here, short length Cherry Rivets are headed on the inside of the tubing.

The Cherry Rivet is a mechanical blind rivet headed by means of a mandrel passing through it. A gun exerts a pulling force on the mandrel, expands the shank of the rivet and forms a tulip head on the blind side, the head on outside conforming to the radius of tube.

If you need to speed up war jobs or are planning new products, get the complete story on Cherry Rivets now. See how they will save time and money. Give you a better job in many types of applications.



Mandrel is pulled into rivet, expands shank, forms head on blind side. Mandrel is trimmed flush.



GET NEW HANDBOOK. See how Cherry Rivets have been proved in aircraft. Write to Department A-107, Cherry Rivet Company, 231 Winston Street, Los Angeles 13, California.

Cherry Rivets, their manufacture and application are covered by U. S. Patents issued and pending

Cherry Rivet Company
LOS ANGELES, CALIFORNIA

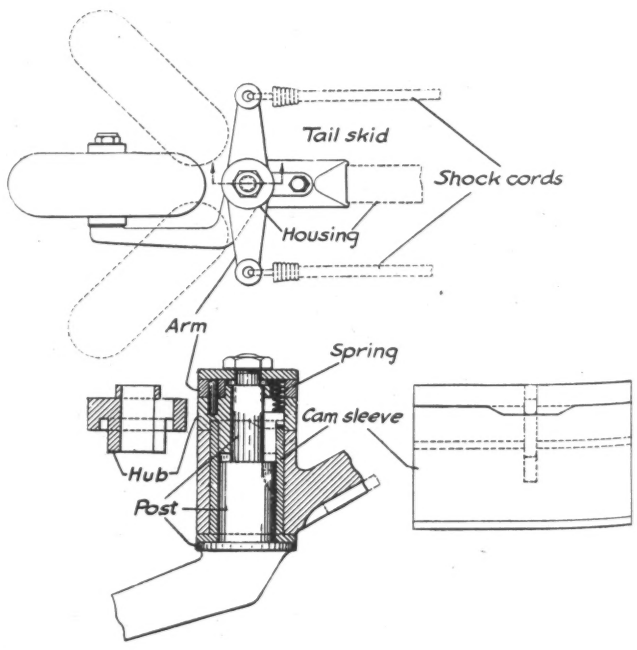
NOTEWORTHY PATENTS

Steerable Caster Tail Wheel

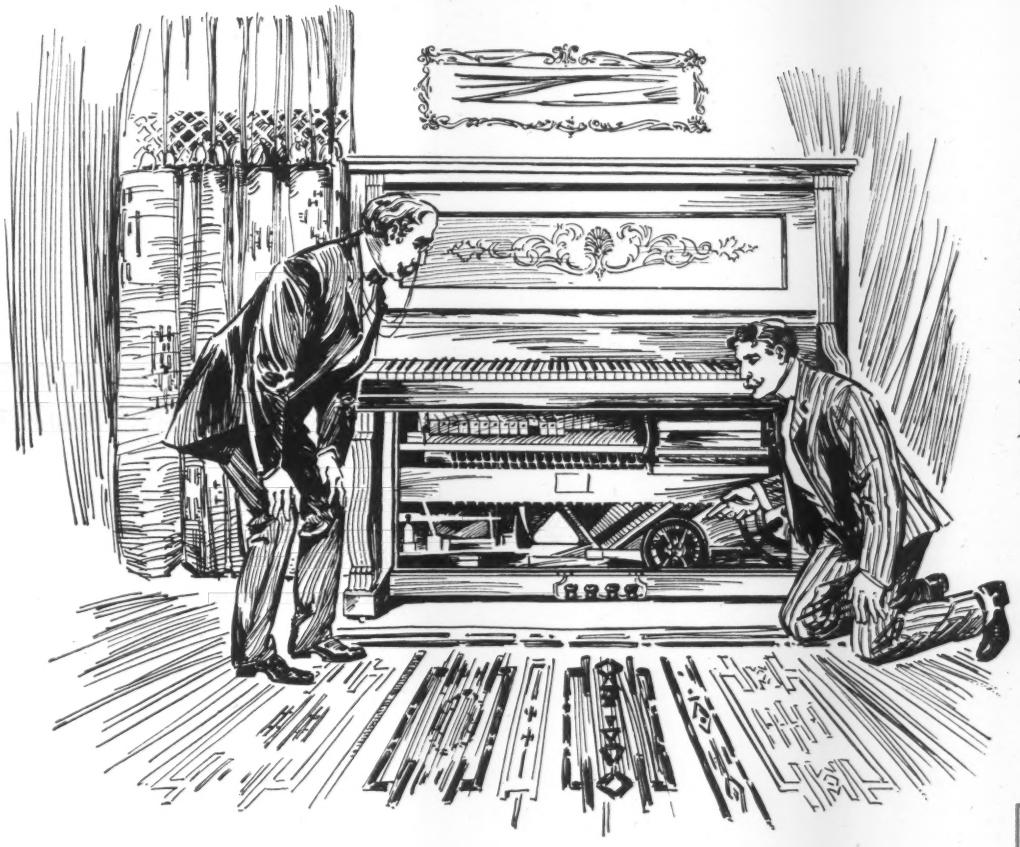
A TAIL wheel which is steerable through a substantial arc yet has full swivel or caster action is covered by patent 2,329,823 recently assigned to Lake State Products, Inc. Developed for use on airplanes having a positive connection between the steering mechanism for the rudder and the tail wheel, the design is such that there is no load or resistance to be overcome in uncoupling the tail wheel from the steering mechanism.

As shown in the accompanying drawing the tail wheel assembly is secured to the tail skid. The wheel is mounted for rotation upon an axle attached to the angular arm which is integral with the vertical post. The steering arm assembly comprises a double-ended arm to the ends of which shock cords are connected for actuating the arm from the rudder mechanism. As shown in the sectional elevation the arm is pinned to a hub which is shown in detail at the lower left of the illustration. A cam sleeve is press fitted and pinned within the housing. This sleeve is shown developed at lower right of the illustration. Upper edge of the cam sleeve engages a key which is pressed against it by a spring. This key is free to slide vertically within a slot in the hub and when in its lowest position engages a keyway in the post.

It will be noted that the post is supported for complete rotation in the housing, that the cam sleeve is fixed to the housing, that the hub is fixed to the steering arm and is



Tail wheel is steered along with rudder within the limits indicated by dotted lines. Beyond these positions full swivel action is obtained



"Look, Harry, with this Emerson-Electric motor, the player piano will play itself!"

"You don't mean, George, that it will really play *without pumping the foot pedals?"*

"That's exactly what I mean, Harry—those motor people are finding new uses for electric motors every day. What will they think of next?"

A "Memorable Event" of 1904—Created by an *Emerson-Electric* Motor

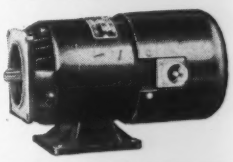
IMAGINE everyone's surprise when, in 1904, a player piano actually "played itself"—an Emerson-Electric Motor had been installed!

This early innovation may seem trivial compared to the contribution of Emerson-Electric Motors in later years. But, it was this early pioneering that helped make present-day motor-driven appliances and equipment possible.

Think of living without electric motors to operate our washing machines, ironers, vacuum sweepers, refrigerators, fans, heating systems, and the numerous types of equipment in industry and commerce. The American way of life is powered with electric motors.

Now, Emerson-Electric is working full time for Victory. Wartime necessities are providing invaluable experience and creative research in a new and vastly enlarged field of manufacturing operations, particularly in light metals and plastics. "After Victory", manufacturers of new and improved motor-driven appliances can turn with complete confidence to Emerson-Electric for motors that will do the job better and stay on the job longer—motors that will meet the challenge of a post-war world.

Emerson-Electric power-operated gun turrets and electric motors for aircraft are in active service on all battle fronts of the world.



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SAINT LOUIS
Branches: New York • Chicago
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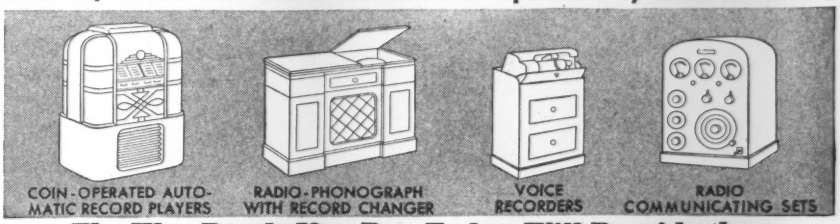
Musical, Sound and Radio Instruments Operated by Electric Motors



The War Bonds You Buy Today Will Provide the Electrical Appliances You'll Want After Victory

355

EMERSON ELECTRIC

MOTORS • FANS • APPLIANCES

FLEXIBLE COUPLINGS by CROCKER-WHEELER

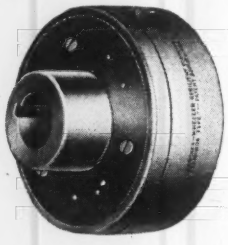
SIMPLE • EFFICIENT • ECONOMICAL

Sizes for shafts from ½" to 5½" diameter in stock for immediate shipment.

Maximum torsional flexibility

Free from noise and vibration . . . cushioned on rubber

No lubrication required



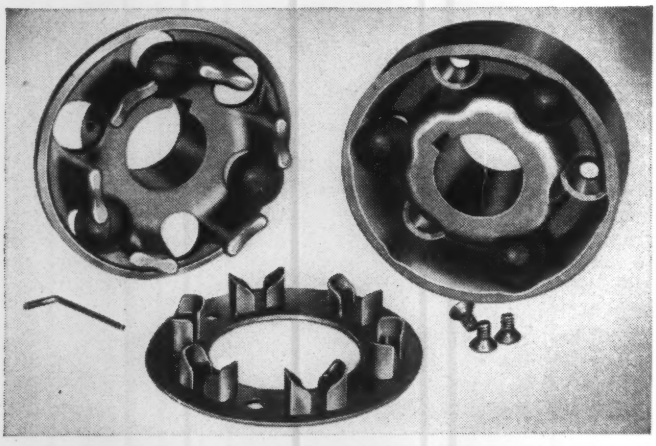
Trouble-free operation

Great shock absorbing capacity

Longer life for machine

Made by a leading manufacturer of motors and generators, the C-W Coupling has only 4 major parts . . . flange, spider, ball retaining ring and rubber balls. The balls transmit the torque, absorb the shock and vibration, but do not transmit end thrust. Nothing absorbs shock like rubber.

The C-W Coupling can be used for every flexible coupling application. It is ideal for use in reciprocating engines where the use of a conventional coupling would transmit the shock of drive or driving machine and cause maintenance problems.



CROCKER WHEELER ELECTRIC MANUFACTURING COMPANY

Ampere, New Jersey . . . division of JOSHUA HENDY IRON WORKS

For engineering and service information, call . . .

*Boston	(COM 6907)	*Detroit	(TR 2-5785)
*Buffalo	(CL 4985)	New York	(CO 7-6700)
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*Cleveland	(MA 3255)	*San Francisco	(EX 5531)
		Washington	(EX 1991)

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OTHER JOSHUA **HENDY** IRON WORKS PLANTS AT SUNNYVALE, POMONA, TORRANCE AND LONG BEACH CALIF., AND ST. LOUIS, MO.

oscillated with it and that the key constitutes the sole coupling element between the post and the spring arm assembly unit. At the time the ariplane takes off or lands the tail wheel will swing the post into a position aligning the key with the keyway in the post, provided the rudder is in a neutral position. This alignment enables the key to drop into the keyway, positively locking or coupling the hub and steering arm to the post. With the tail wheel and rudder in the position just described the nose of the key will be riding on the lower horizontal portion of the cam defined by the upper edge of the sleeve. Movement of the arm will enable the tail wheel to be positively steered within an arc corresponding to the lower horizontal portion of the cam. With nose of the key riding on the upper horizontal portion of the cam, the post is uncoupled from the steering arm so that there is no interference with the full swivel or caster action of the tail wheel. The uncoupling and coupling of the tail wheel from and to the rudder steering action is fully automatic, requiring no attention from the operator and is accomplished without addition of any appreciable resistance to swivel movement or use of an overload release. In practice the cam may be designed to give steering control over the tail wheel through a 90 degree arc with free swivel action through the remaining 270 degrees.

Shutter Actuated by Geneva Mechanism

MANY attempts have been made to produce a between-the-lens type of camera shutter in which extremely rapid exposures of the order of 1/1000-second could be made where the aperture is in the neighborhood of 1½ inches. Because the parts must be moved with extreme rapidity, it has been difficult to start and stop the movement without damaging the shutter leaves and other parts of the mechanism. An improved shutter which is covered by patent 2,327,780, recently assigned to Eastman Kodak Co., overcomes the defects of previous shutters by making the parts which must move rapidly in such a way that the prime mover reaches a high acceleration before the shutter blades are actually moved. Provision is also made for preventing the rebound of the suddenly stopping shutter blades.

As shown in the accompanying illustration the shutter is of the type in which a number of shutter leaves are mounted to turn one complete revolution when a torque is applied to them by means of a ring gear and pinion. The ring gear which drives the shutter pinion is included in a Geneva driven member which is moved a distance sufficient to rotate each shutter blade pinion one revolution for each exposure.

Referring to the lower view it will be noted that the Geneva driver is actuated by one end of a spring, the other end of which is anchored in a winding knob. This structure constitutes the master member. The post supports a ratchet in a stationary position, whereby the winding knob may only be turned in one direction—in this instance counterclockwise—in setting the shutter and in tensioning the master member to make an exposure. The Geneva driver includes a plate and sleeve which carries near the top an arm supporting the sleeve pin. This pin passes through the same path as the knob pin which

There's still a big job for all of us to do

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For you and for us there's *still* a big job to be done. The history of the amazing production performance of American industry is *still* to be written.

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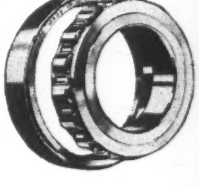
As soon as the war's won, and this job is done, Industry and Hyatt will have another big job to do together... when we can work in Peace.

Hyatt Bearings Division, General Motors Corporation, Harrison, N. J.

DIVISION OF

HYATT BEARINGS  **GENERAL MOTORS**

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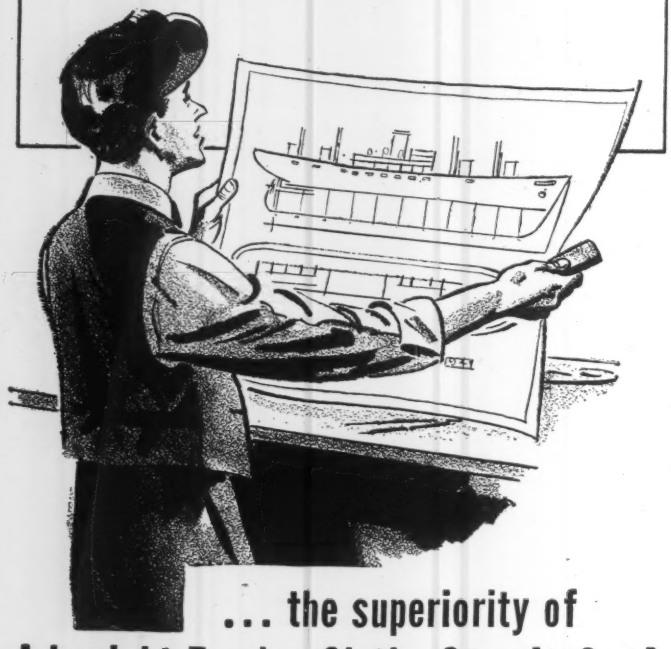

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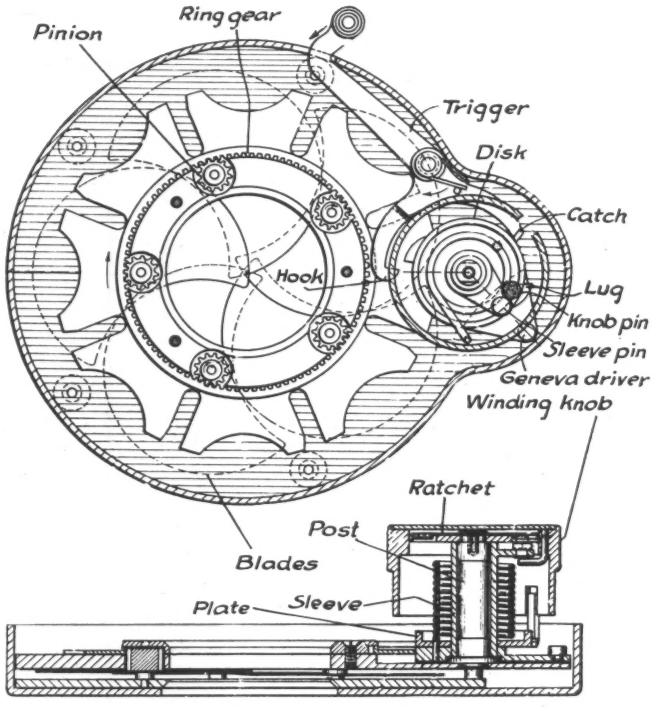


Trigger releases spring-wound Geneva driver which attains high speed before engaging driven member, thus providing rapid shutter action

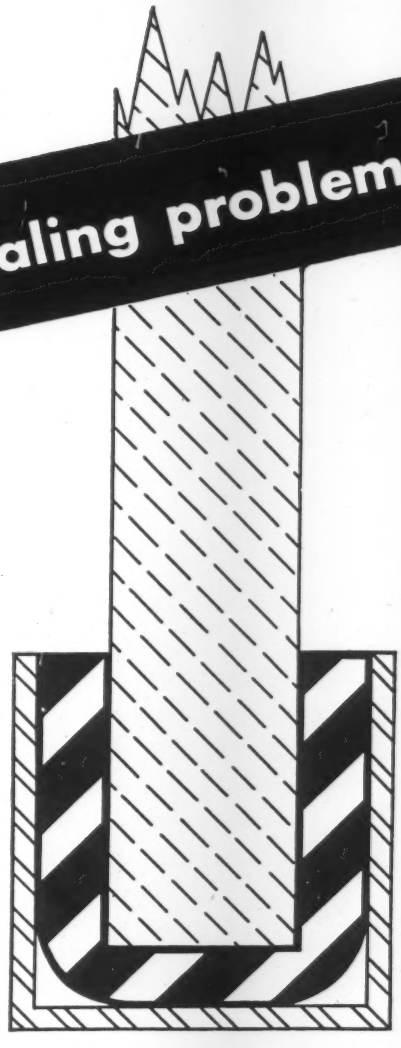
forms a stop to prevent the knob from being overturned in winding.

In the upper view the shutter is shown ready for the winding operation. The knob may be turned a single turn or one or more short turns as desired since rearward movement is prevented by the ratchet mechanism. During winding, the knob pin passes away from the sleeve pin as illustrated since the Geneva driver is held in the position shown by means of a lug carried by the Geneva plate coming in contact with the end of the camera trigger. The trigger is pivoted upon a stud while a spring tends to hold the trigger releasing handle in an outward or operative position. Thus, the end of the trigger holds the lug and with it the Geneva driver against movement until the trigger is released. When the knob pin comes to a stop against the sleeve pin the shutter is fully set.

To make an exposure the trigger is released by pressing in the direction indicated by the arrow, thus releasing the lug which, in the fully wound position, was in contact with the catch end of the trigger. This permits the Geneva driver to swing rapidly in a counterclockwise direction, gaining speed as it travels through approximately 100 degrees, then engaging one of the slots in the Geneva driven member and moving it one step.

It will be evident that if the trigger could be depressed and released rapidly enough the lug would be all that is necessary to prevent the spring from unwinding. However, since the exposure is extremely rapid it is impossible to rely on the end of the trigger returning to the path of the lug before the exposure is complete. Therefore, a second stop in the form of a hook is provided on the trigger so that a second lug may be caught if the trigger is depressed and held down during exposure as is customary.

Do you have a sealing problem like this?



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ASSETS to a BOOKCASE

Design of Machine Members

By Alex. Vallance, chief designer, Reed Roller Bit Co., and Venton Levy Doughtie, professor of mechanical engineering, University of Texas; published by McGraw-Hill Book Co. Inc., New York; 559 *pages,* 5⅛ *by* 8¼ *inches; clothbound; available through* MACHINE DESIGN, $4 *postpaid.*

True proficiency in machine design is not based solely on theory, nor for that matter on experience alone. Recognizing this basic fact, the authors of this book seek to point out the variations from theory required in practical applications. There can be little doubt that this approach is logical and of considerably more value to the practicing designer than are many purely technical treatises on the same subject.

While the book is primarily intended to aid the young designer, there is much in its content which should also prove of interest to the experienced man. In an early chapter the subject of engineering materials is discussed with forthright competence and covers such pertinent considerations as strength, stiffness, ductility, toughness, resilience, hardness, machinability, casting and forging properties, etc. Subsequent chapters deal with stresses in elementary machine members, all types of joining methods, factors influencing the design of shafting, couplings and clutches, springs, brakes, various bearing types, many power transmission systems, and miscellaneous machine members.

□ □ □

Elements of Mechanical Vibration

By R. C. Freberg and E. N. Kemler, professors of mechanical engineering, Purdue University; published by John Wiley & Sons, Inc., New York; 193 *pages,* 5⅜ *by* 8 $\frac{5}{16}$ *inches; clothbound; available through* MACHINE DESIGN, $3 *postpaid.*

An elementary approach to the solution of vibration problems through the use of the simpler forms of differential equations and approximate or mobility methods. In short, a treatise specifically designed to fit the needs of those not thoroughly versed in the most advanced phases of mathematics.

After a preliminary dissertation which briefly presents the varied engineering applications of vibrations, the reader is acquainted with the nature of undamped vibrations. Here, the familiar spring and weight examples are employed for illustration and methods of solution are explained. In the same section, problems concerning the manometer, pendulum, disk and shaft, etc., are dealt with.

Ample consideration is given damped vibrations, such as the viscous-damped types, forced types and steady-state forced types. Further discussions present data on vibration of systems with several degrees of freedom,

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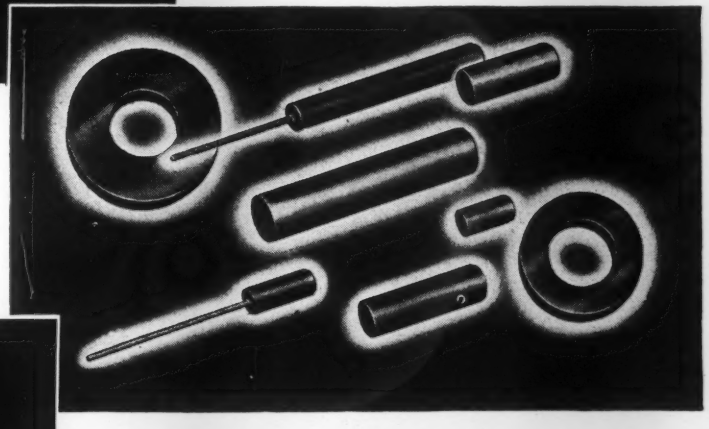

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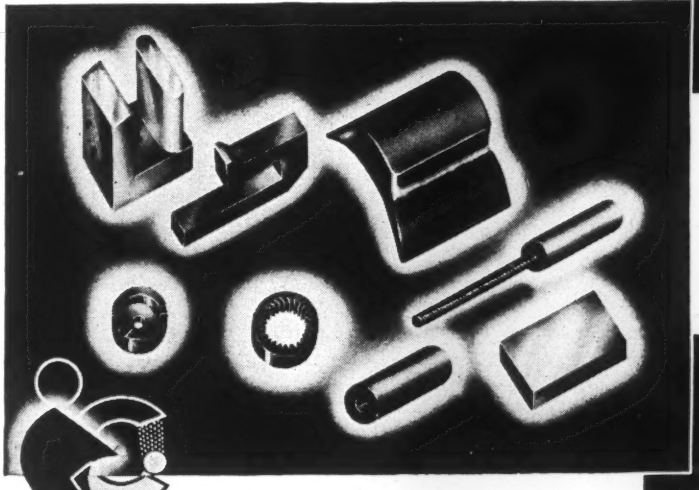

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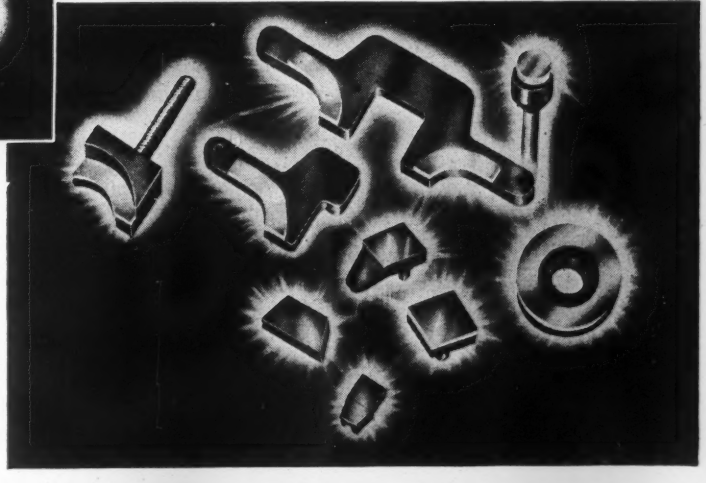

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vibration isolation and absorption, equivalent systems, the mobility method, and mechanical and electrical models of vibration systems.

Drawings and graphs are generously employed throughout and an up-to-date bibliography is included.

□ □ □

Studies in Arc Welding

Published by The James F. Lincoln Arc Welding Foundation, Cleveland; 1295 *pages,* 5¾ *by* 8⅝ *inches, clothbound; available through* MACHINE DESIGN, $1.50 *postpaid.*

Based on studies conducted by 113 authorities in the welding field, this book comprises 98 of the most significant award papers in the 1940-42 program of the James F. Lincoln Arc Welding Foundation.

Arc welding techniques as applied to the fabrication of a wide variety of mechanical structures are thoroughly elucidated, each award paper serving, for all practical purposes, as a case history of a specific project.

Emphasis is accorded influencing design factors such as: Strength calculations, economy of materials, time saving, facility of production, durability, weight comparison, etc. Most of the chapters are capably illustrated and the pertinent engineering data supplied are clearly rendered.

Data included applies to a wide variety of equipment used in fields classified as: Automotive, aircraft, railroad, watercraft, structural, furniture and fixtures, commercial welding, containers, and machinery.

□ □ □

Plastics

By J. H. DuBois, B. S., Plastics Department, General Electric Co.; published by American Technical Society, Chicago; 435 *pages,* 8¼ *by* 5½ *inches, clothbound; available through* MACHINE DESIGN, $3.75 *postpaid.*

This book, an expansion of a previously published text, gives the practical design man what he wants to know about plastics. Commendably, its author recognizes that the man who uses plastics for machine parts is primarily concerned with what he can do with the materials and is not particularly anxious to become a chemist.

While the chemical constituency of the various plastics is explained, the treatment afforded this phase of the subject is fittingly brief. Emphasis is placed on the "how to use" and "what to use for" angles.

Chapters dealing with the many thermosetting and thermoplastic materials are followed by descriptions of molding techniques, factors influencing materials selection, designing with plastics, low pressure laminating, trends and developments, and a separate chapter on synthetic rubbers.

Replete with illustrative photographs and drawings, the book also includes many charts to acquaint the reader with the properties and characteristics of the materials described.

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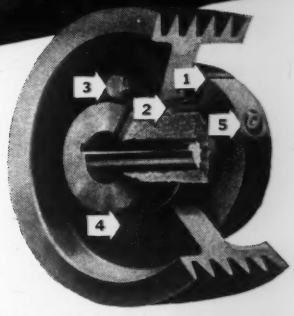

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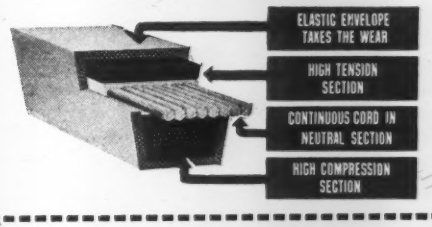

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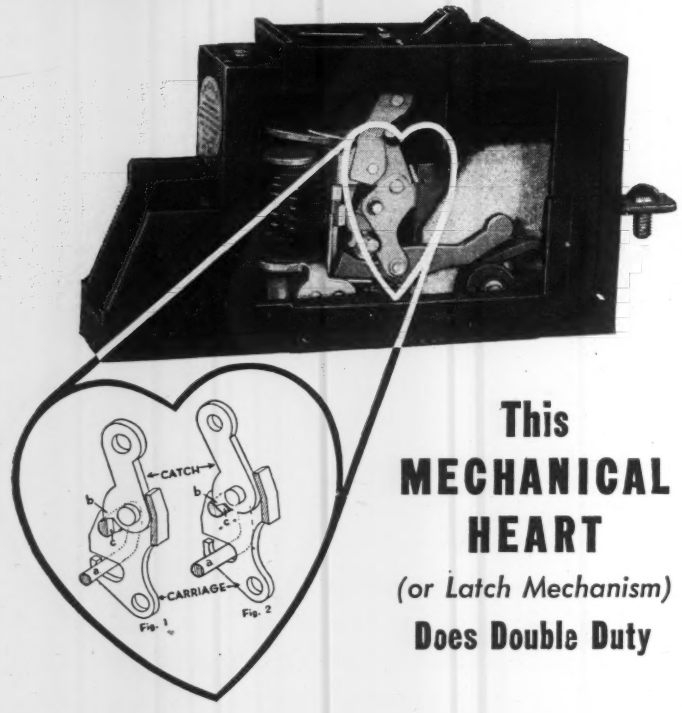

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The relative position of the catch to the carriage remains the same as in Fig. 1 whether the handle is in the "on" position or turned to the "off" position, when the contact is broken manually. The latch collapses only under overload or short circuit conditions—*and it does that even if the handle is purposely held in the "on" position.* Fig. 2 shows the latch on its way to the collapsed position.

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Induction Heating Machine

(*Concluded from Page* 139)

characteristics of the circuit. Design features are the same as those incorporated in the water-cooled gaps except that cooling is effected by the forcing of air through copper fins. These fins are soft-soldered into the brass castings after brazing of the tungsten surfaces.

Accessory features included with this type of machine are the quench rings and rotating device for hardening. Original design included quench rings made of brass castings. One of these took the form of a channeled circular ring and to its outer diameter was brazed a flat brass ring. Holes were drilled on the inner diameter to provide the water spray, and a base to support the ring was made from cast aluminum. To obviate the necessity of a base for every ring, mounting holes were drilled at various intervals on the base to accommodate various ring sizes.

Because of the difficulty in procuring critical materials such as brass and aluminum, a substitute material had to be found for the quench rings, and molded plastic offered a logical solution. Design of these plastic rings is fundamentally the same as for the brass rings. The channeled circular part was molded first, and after it became hard the top ring was molded to it, making a solid unit. The spray holes were drilled with a templet after molding. A

Fig. 7—Heating and quenching unit shown mounted in utility cabinet

corresponding base for the ring was molded from plastic material and this base also served for three different sizes of rings.

Applications of this type of heater cover a wide field, such as hardening, brazing, soldering, tempering, forging, annealing, and melting. Type of work that can be done is restricted only by the capacity of the machine. A variety of work coils is employed to accommodate different applications, the coils being made to suit the specific work to be done. These coils are made from copper tubing, ranging in size from ⅛-inch for small coils to 5/16-inch for large size coils. All such coils are water-cooled, and last indefinitely when properly used. Any one of them can be attached to the unit merely by connecting it to the output leads of the converter.

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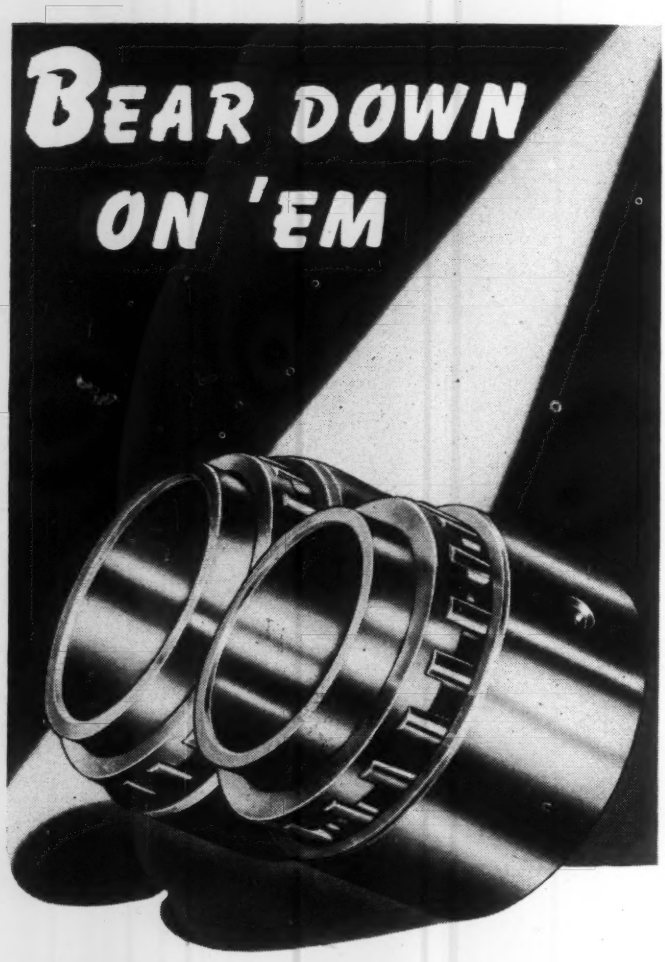

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Brazing

(*Continued from Page* 123)

while it is easy to maintain accurate temperature control. It is necessary that the bath be large enough so that there is no appreciable temperature drop when the cold parts in their fixtures are first introduced into the bath.

Shown in *Figs.* 13, 14, 15 and 16 are some brazed assemblies which illustrate well some of the interesting designs made possible by brazing techniques. The overrunning clutch part in *Fig.* 13 was formerly machined out of a solid 1¾-inch bar on a 2-inch automatic screw machine, after which the splines and drilled holes were cut. With 7000 to 8000 parts required per day, the whole procedure was relatively slow and costly. An improved method was subsequently employed in which a 1¾-inch collar was upset on a one-inch bar, which saved some machining but was still slow.

Improved Fabricating Technique Described

Using the copper brazing process, the present method of fabrication is as follows: The clutch end of the part, including a small hub adjacent to the clutch, is machined from 1¾-inch bar stock and reamed to accept the stem portion of the assembly, which is produced from tubing. The parts are pressed together and a ring of 18-gage copper wire is applied to the stem adjacent to the hub of the clutch portion, after which the assembly is passed through a continuous brazing furnace where the copper melts and flows into the joint. Following the brazing operation, the part is carburized to produce a case of approximately 3/64-inch depth, then hardened by quenching in oil from 1475 degrees Fahr. and tempered at 900 degrees.

Selected parts are tested by locking the clutch end in a fixture and applying a torque load to the stem end through an adapter. The normal result is that the stem breaks off adjacent to or away from the brazed joint, but never within the brazed joint, indicating strength equal to that of the solid part. The use of copper brazing in the production of this particular unit effected a saving of approximately five cents per part.

Example Illustrates Preplacing

Another brazed assembly is shown in *Fig.* 14. The crankshaft is assembled from two side plates and two pins pressed together, copper brazed and cyanide hardened. Grooves cut in the pins hold the preplaced copper wire during assembly and heating. The brazed unit is then pressed on to the driveshaft, drilled and pinned.

The part shown in *Fig.* 15 is a steel housing used on tank guns as part of the firing mechanism. It is made by brazing together a machined steel cup and a forged steel saddle, the brazing operation being completed in about a minute with a gas torch and using about 2½-cents worth of silver brazing alloy and flux. The surface of the saddle is first brushed with paste flux then strips of alloy .005-inch thick are placed on the wet flux. Cup surface is then fluxed and the parts placed together in an inverted position so that the cup rests on the inverted saddle. Fol-

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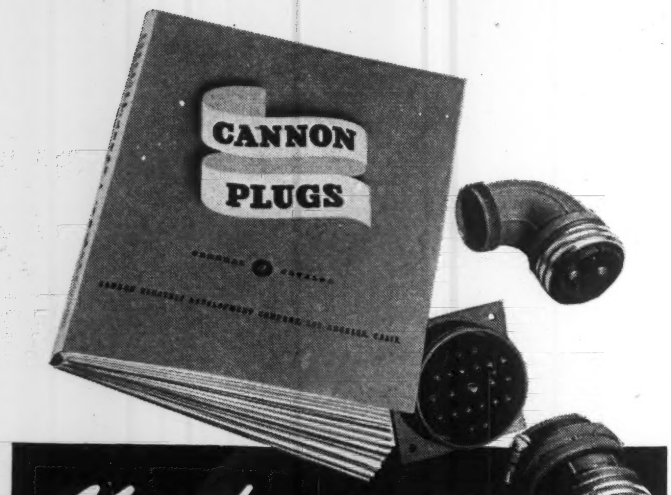

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lowing the heating and brazing of the assembly, excess flux and oxides are removed by pickling.

How weight can be saved through the use of brazed steel assemblies is well demonstrated by the automobile clutch-gear bearing retainer shown in *Fig.* 16. The malleable casting at left weighs 2.5 pounds and after machining weighs 1.5 pounds (center). The new construction, right, which replaces it, using steel tubing and a stamping copper brazed in a controlled-atmosphere electric furnace, weighs only half a pound.

The foregoing examples will indicate to the designer some of the possibilities of brazing as a method of economically producing machine parts. Manufacturers of brazing equipment, supplies and materials have gained wide experience in assisting with the development of such parts, and will be found ready to share their knowledge and skill in solving new problems.

MACHINE DESIGN is pleased to acknowledge the cooperation of the following companies in the preparation of this article: Boice Crane Co. (*Fig.* 14); The Electric Furnace Co. (*Fig.* 13); Eutectic Welding Alloys Co.; General Electric Co. (*Fig.* 16); Handy & Harman (*Figs.* 9, 10 and 15); Induction Heating Corp. (*Fig.* 11); The Ohio Crankshaft Co. (*Fig.* 12); Westinghouse Electric & Manufacturing Co. (*Fig.* 8).

KETTERING on Inventors

(*Concluded from Page* 112)

spring, as furnished by eight or ten steelmakers, broke at about the same time—a couple of thousand cycles. That checked very well with the formula. Then we asked each one of the steel people to run a test and see how they checked, and they checked about the same thing; in other words the formulas and the experiments agreed.

Then we gave some more samples a simple treatment of surface peening, using little steel balls—shotblasting, or whatever you want to call it. Those springs didn't break at two million cycles. Now, that is why we question formulas, because that is quite a gain in per cent. We don't know what it does. All we know is that it is effective, but we think we have now got the science of it worked out.

In all these things we never get discouraged—because it takes a number of years from the time you start a thing before you get it finished. The psychology of the presentation of an invention, which I said some technical fellows are so poor at, is as important as the technical. Even as far removed from sales and all that kind of stuff as our research laboratories are, I still think that we are about 40 per cent technical and 60 per cent psychological.

Therefore, we have to teach these boys how to get along with people, especially when they are working on a new thing and everybody comes in and says, "What the hell are you doing that for? That is no good." We have to keep their spirits up under those conditions.

So we believe that we can even take educated young men and teach them to be inventors, without ruining their education. We teach them to make as much out of the thing that they know—their chosen profession, their chosen line—as they can, without having to fake the idea that they are superhuman individuals.

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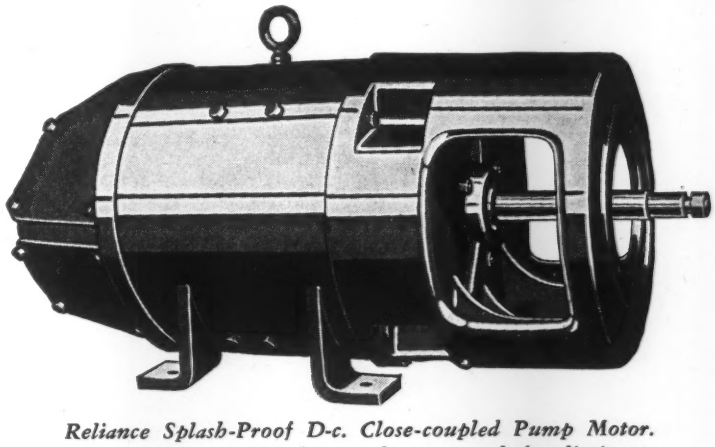

Reliance Splash-Proof D-c. Close-coupled Pump Motor. Pump is mounted right on the motor shaft—eliminates misalignment, saves space; fewer parts, less maintenance.

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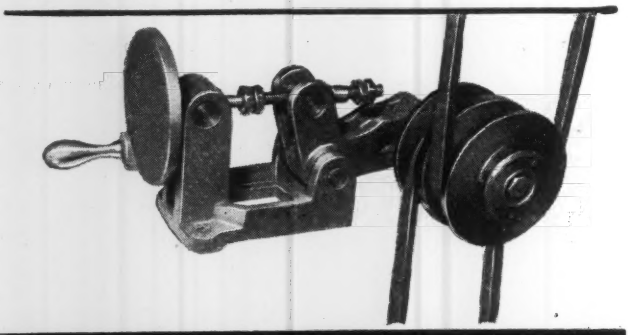

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Self-Contained Units

(*Continued from Page* 119)

the CRT2 contact marked "closed, returned", and thence through the "transfer set-up relay contacts" to relay number one.

These transfer set-up relay contacts will be closed only when all the machining heads have completed their work cycles. In other words, should one of the heads fail to advance fully, perform its machining operation and return to its "back" position, its relay contact will be open and the circuit to relay number one will not be completed.

As explained previously, the locator pins are actuated by hydraulic cylinders, the four-way valves of which are controlled by solenoids. In this case current will pass through the contacts of relay number one to the energizing coils of the locator pin solenoids. Thus the locating pins will be withdrawn from engagement with the fixtures and the machine is ready to perform its next operation—the transference of all loaded fixtures to succeeding machining stations.

It will be seen that, were the "transfer set-up relay contacts" not in the circuit just discussed, it would be possible for the machine to pass the loaded fixtures throughout the complete operational circuit of the machine with the part lacking one of the machining operations.

Path taken by the current to reach coils of relay number two is identical to that previously employed up to the two-line juncture immediately past the normally closed contact CRT2 marked "closed, returned".

With the locating pins out of engagement with the fixtures, the current is free to pass through the closed contacts marked CRL1, CRL2, etc. Before reaching relay number two, the current must pass through contacts CRS1 and CRS8. The first of these will be closed only when loading station number one is loaded with a fixture while the second remains closed only when machining station number eight is empty.

Necessity for these last two contacts will become apparent upon considering the locations of stations numbers one and eight. Number one is at the front left-hand corner and number eight is at the rear left-hand corner. Since loaded fixtures are moved by the transfer bar from the front to the rear of the machine, should station eight be loaded and the transfer bar be advancing, there would be a collision of fixtures at this station. In the case of station number one, if it were empty when the transfer bar advanced, all machining operations throughout the entire circuit of the machine would be utterly wasted, since no part would be present to receive them.

With current feeding through number two relay to the valve-actuating solenoid of the transfer-bar hydraulic cylinder, the transfer bar will be propelled to its advanced position, moving the loaded fixtures along with it to the next machining station.

With all seven loaded fixtures along the left-hand side of the machine at the machining stations, the locating pins must be brought into engagement with the bushing holes on the undersides of the fixtures. Simultaneously the fixtures will also be clamped in place. To set these operations in motion requires that relay number three be

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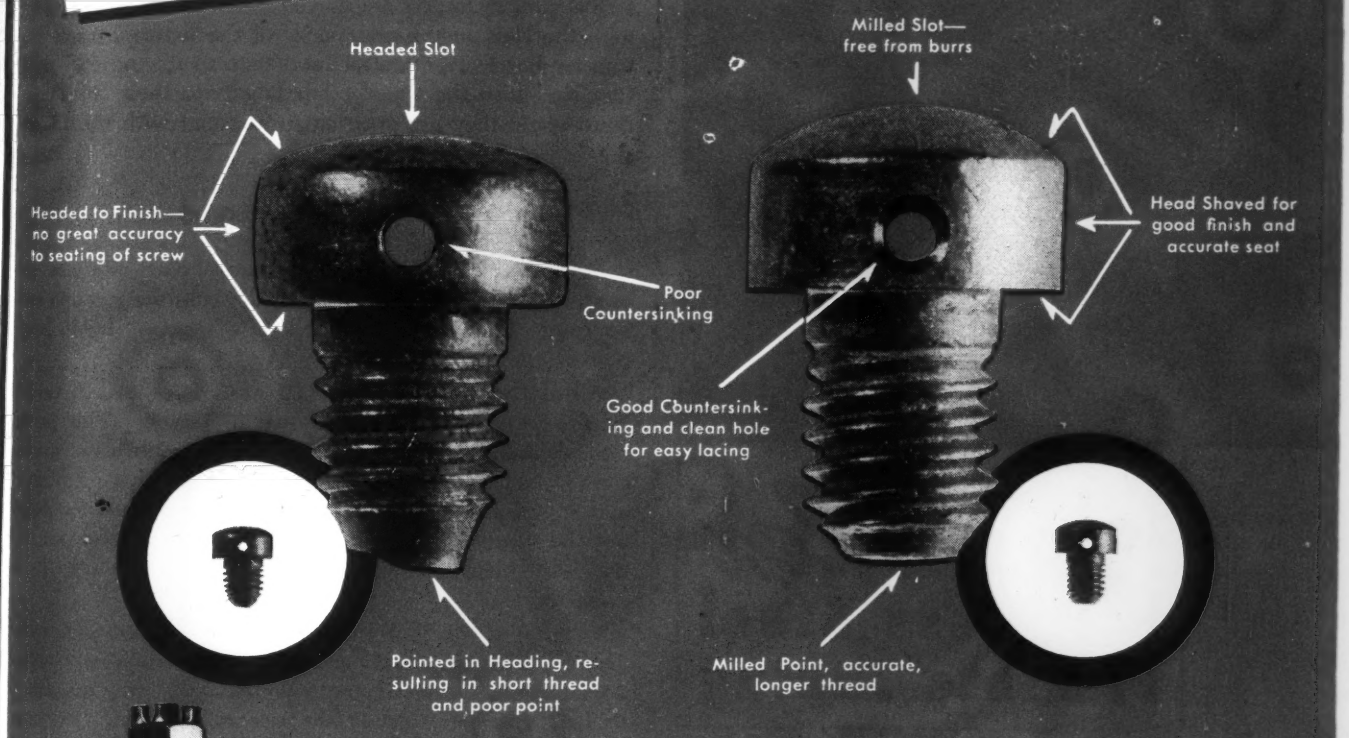
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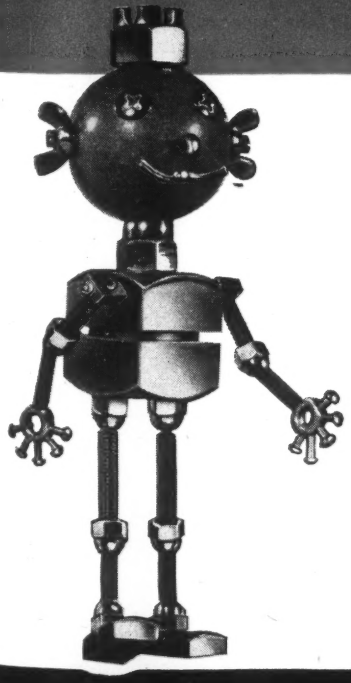

A customer making aircraft complained about some screws and sent us a batch of them. One look and we saw that they were not ours. The contrast between the other screws and National's was striking.

In order to make the difference clear we show above photographs of one of the screws made by ordinary production methods, and one of ours, together with actual magnifications of these same photographs.

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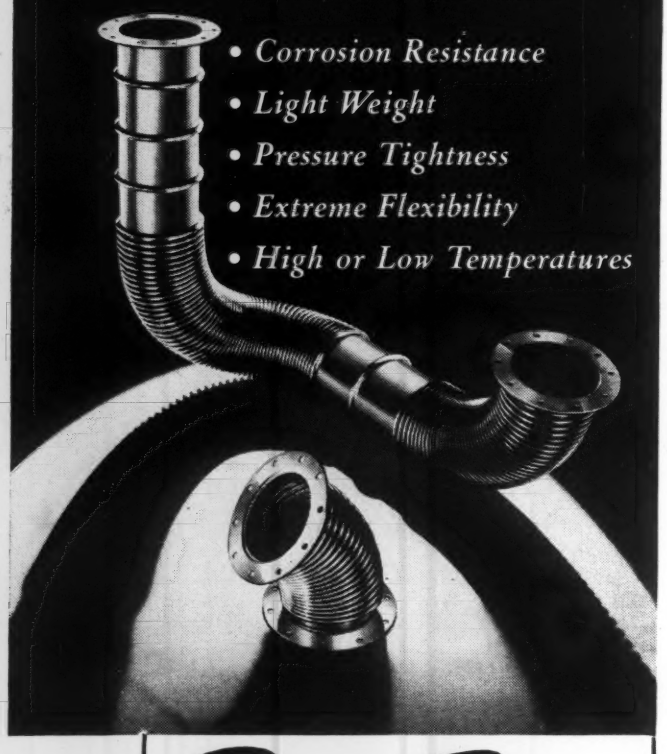

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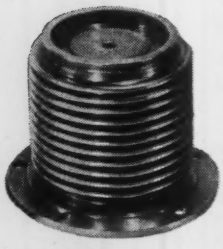

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energized. Once again, starting at "B" on the schematic diagram, the same circuit is traversed up to the juncture between contacts CRT2 and CRTF2. From this juncture the current feeds through the cycle relay CRC and also through contact CRT2 marked "closed, T2 advanced" to relay number three. Here again, as was the case with relays number one and two, current from the relay serves to energize hydraulic-cylinder valve solenoids. This time, of course, hydraulic pistons drive the locator pins into engagement with the fixtures and also actuate the fixture clamps.

Subsequent operations numbered 4, 5, 6, 7 and 8 bring the machining heads forward at the same time the transfer-bar pins or fingers are moved down out of engagement with the slots in the undersides of the fixtures, move the transfer bar to its "neutral" and then to its "return" position, and turn the transfer bar fingers to their "up" positions where they are once again engaged with the fixture slots.

Circuits Are Interlocking

By tracing the circuits which control each of these operations it will be seen that, in all cases, the circuits can be completed only after previous operations have been performed.

All of the control relays, 129 in number, are mounted on the main control panel shown in *Fig.* 6. This panel also contains sixteen time relays, twenty-three motor starters and a step-down transformer. For driving pumps and spindles, twenty-three motors are employed throughout the machine along with fifty-six solenoids for actuating the hydraulic cylinder valves and ninety limit switches.

In spite of the "foolproof" interlocking circuits just described, there is always present the possibility of a hydraulic unit, electrical contactor, switch, etc., becoming fouled, thus interrupting the operating cycle. Without some convenient means of quickly determining the exact spot at which trouble develops, the job of tracking down the offending units would be extremely laborious.

By means of the "trouble-shooting" pushbutton cabinet shown at the front left-hand corner of the machine as illustrated in *Fig.* 1 and separately shown in *Fig.* 7, difficulty arising at any point on the machine can be located almost instantly. For example, if a transfer bar does not assume its correct position at a given time in the operating cycle, one of the lights—grouped in twos on the black portion of the cabinet panel—will go out, indicating to the machine's operator the exact spot at which trouble has developed.

Being quite large, the base structure of this machine did not lend itself to one-piece construction. It is made up of a number of castings bolted together. In designing these individual castings the designer was required to give due consideration to a number of influencing factors. For one thing, size of the machine tools used for finishing the castings imposed a definite limit on their overall dimensions. Again, spacing of the spindle stations had to be taken into account. Finally, the individual castings, along with other component parts, had to be shipped on railroad flat cars, the width of which imposed a third size-limiting factor.

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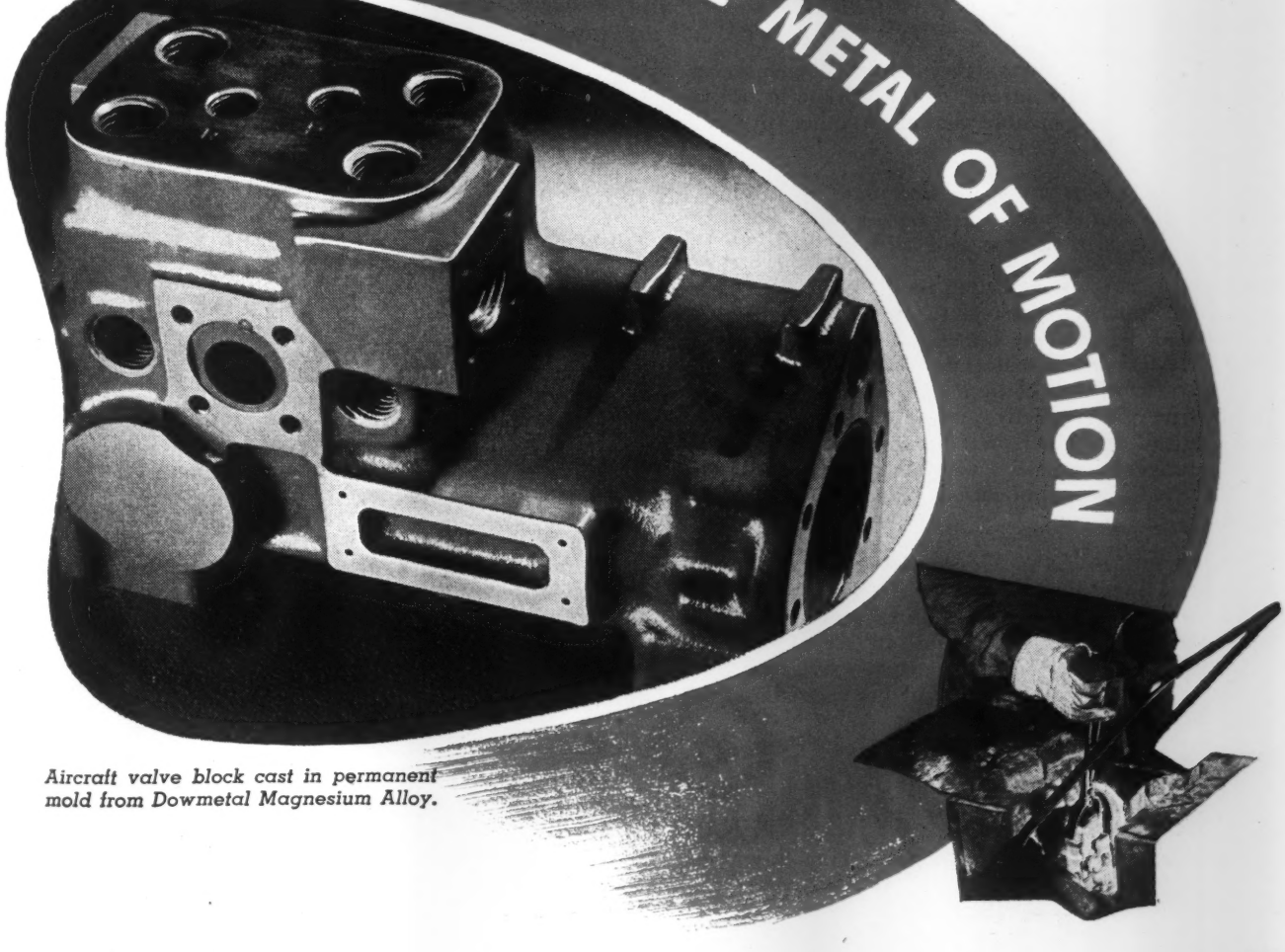

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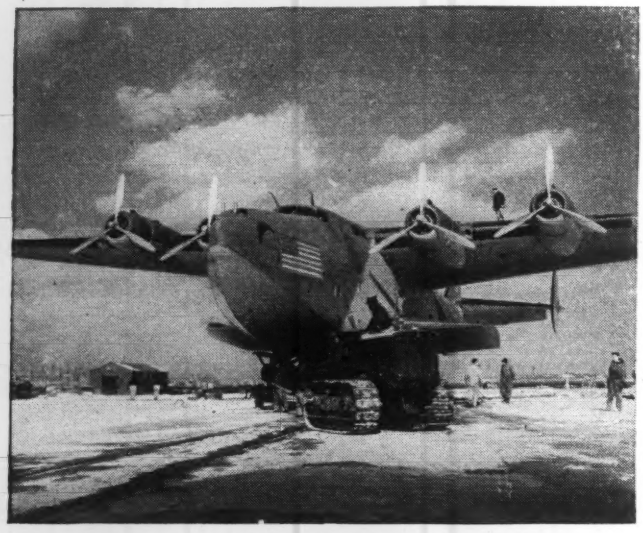

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WILCO

Choosing the Right Material

(*Continued from Page* 133)

Heron, Harder and Nestor[10] comment on the satisfactory application in aircraft engine exhaust valves of hard steels with Izod notched-bar impact values of less than 2 foot-pounds at room temperature, in spite of an earlier statement by Aitchison[11] that high impact resistance is needed, but they draw an interesting distinction between material with around .5 foot-pound and that which is "glass brittle". They bar "exceedingly brittle" materials but do not attempt to pick any specific impact figure as a dividing line.

It would be unfair to class cast iron as a glass-brittle material, for it has a kind of toughness, and various cast irons have various degrees of toughness as indicated by deflection in the transverse test and by impact tests on unnotched bars. When shock is not involved in service cast iron is not handicapped but, when it is involved, as in the case of a "near miss" of a bomb falling near a ship with cast iron valves and fittings in its piping, the cast iron parts may shatter and a tougher material has to be used.

Malleable cast iron is a material in which single-blow notched-bar impact tests give figures that do not indicate much toughness. Yet malleable is used in tank track guides and in brackets for 3-inch guns, among many other applications where toughness appears important. Frye[12] illustrates the battering that malleable endures in some ordnance applications. The malleable producers evaluate their product by repeatedly dropping a 21-pound tup falling 3 1/3 feet, thus producing 70 foot-pounds at each blow, on a wedge 1-inch wide, ½-inch thick at the butt, 1/16-inch thick at the tip, curling it up into shape reminiscent of the dandelion curls the kids make. The test is carried to thirty blows if no crack results, or stopped at the first crack.

A comparison of results from this test and from the regular Charpy notched-bar single-blow impact test is shown in *Fig.* 15 for a regular malleable iron, as received. It's the notch, rather than the impact, that is to be avoided.

In spite of having only a fraction of a foot-pound notched-bar resistance, zinc-base die castings are used in shock absorbers on Army jeeps. If engineers had insisted on high ductility and high resistance to impact on a notched-bar and, hence, had disregarded the possibilities of zinc-base die castings, they would have cut themselves off from great savings in production obtained through the ability of the alloys to be die cast with very small dimensional tolerance, so small that no machining at all is required on many parts.

Annealed stainless steel of the 18-8 type is not injured by low temperature. An 18-8 steel gave the results shown in TABLE V for a water-quenched ("quench-an-

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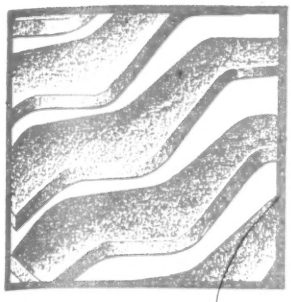
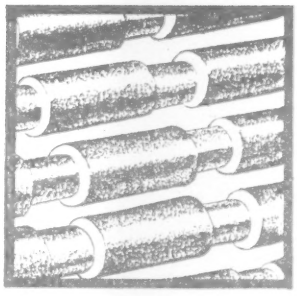
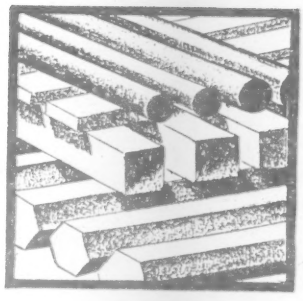
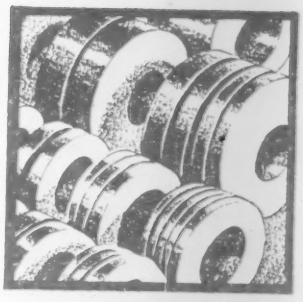
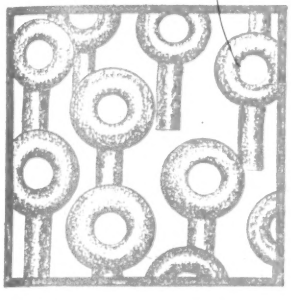
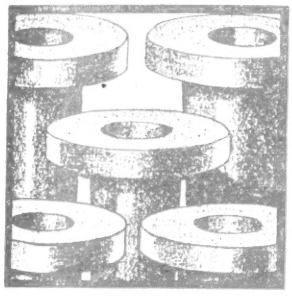
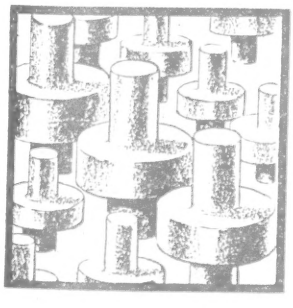
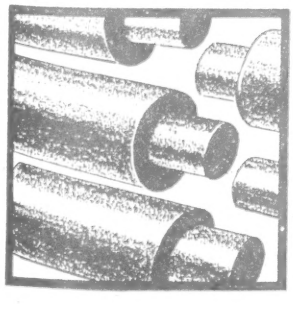
[10] Heron, S. D., O. E. Harder and M. R. Nestor—"Exhaust Valve Materials for Internal-Combustion Engines", Symposium on New Materials of Transportation. *Proceedings* A.S.T.M., Vol. 40, 1940, Pages 1-26.

[11] Aitchison, L.—"Valve Failures and Valve Steels in Internal-Combustion Engines", *Proceedings* Inst. Auto Eng. (London), Vol. 14, 1919-1920, Pages 31-72.

[12] Frye, J. H.—"Malleable Iron Castings in Ordnance, *The Foundry*. Vol. 71, Sept. 1943. Pages 102-104, 162-163.

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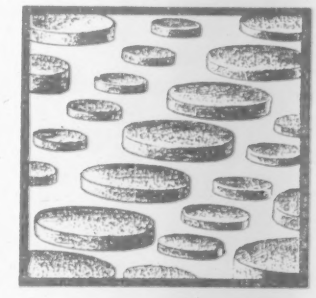
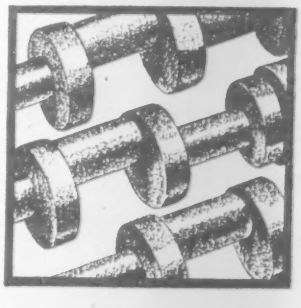
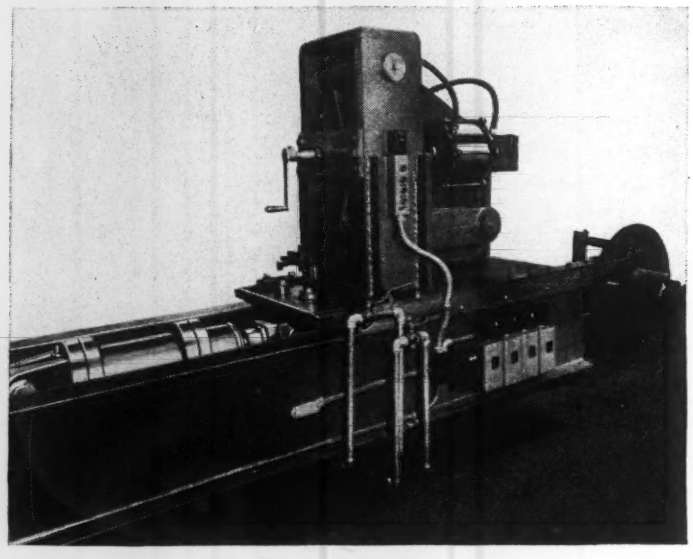




HANNIFIN CYLINDERS

used on the Medart Stretcher-Leveler



Stretch straightening of strip brass or aluminum is handled rapidly and efficiently on this Medart Stretcher-Leveler, with the clamping action provided with a Hannifin air cylinder, and the stretching pressure applied with a Hannifin hydraulic cylinder. The clamping air cylinder is a 12 inch Model BR clevis mounting type with 6 inch stroke, providing smooth, powerful clamping action. The stretching action is provided by a 6¼ inch hydraulic cylinder, 12 inch stroke, with cushioned head end, designed for 2000 lbs. working pressure.

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CYLINDERS

nealed") low carbon 18-8, and for an annealed 18-8 with molybdenum.

Wiester[13] states that the chromium-manganese and high manganese types of austenitic steel are as impact resistant at liquid air temperature as the nickel-chromium type.

The increase in tensile and yield strengths at low temperature is characteristic of metals and alloys in general. Copper-base, nickel-base, and aluminum-base alloys retain much or all of their tensile ductility at low temperatures, in spite of the increase in strength. Their notched-bar impact resistance also tends to remain close to the room temperature level. They appear even better materials of construction at low than at normal temperature. Magnesium-base and zinc-base alloys may decrease somewhat in tensile ductility ,and the already low notched-bar values may also decrease, as the temperature is lowered.

The nonferrous materials, as a class, appear capable of considerable cold working without becoming temperature-sensitive in tensile ductility or notched impact.

It is the ordinary structural and heat-treatable steels whose response to the type of applied stress, and whose alteration in the ratio of shear strength to cohesive strength through cold work or through lowering of temperature, results in brittle behavior. The original room temperature ductility and notched-bar impact figures of the ordinary steels are decreased by factors that increase

TABLE V

Effect of Low Temperature on 18-8 Stainless

Condition	Temperature (F)	Tensile (psi)	Yield (psi)	Elong. (%)	Red. Area (%)	Impact (ft-lb)
Water quench	70	99,000	35,000	56	78	150-166
	—105	179,000	50,000	36	70	117-135
Annealed	70	102,000	52,000	42	72	67-73
	—105	153,000	73,000	51	68	69-90

hardness, such as high-carbon content, cold work, low tempering temperature, after-quenching, etc. But the tensile ductility and the notched-bar behavior do not necessarily go down hand in hand as the temperature is lowered. Indeed, the tensile test usually shows almost as much tensile ductility at —240 degrees Fahr. as at room temperature, though at —320 degrees Fahr. it may fall to under 5 per cent elongation or reduction of area, or may continue to remain nearly as high as at room temperature.

A sharp drop in the value returned by the conventional notched-bar test may, however, occur at only moderately low temperature, as is shown in *Fig.* 16. The sharp drop is accompanied by a change in the appearance of the fracture; on the upper branch of the curve the fracture is a fibrous, tearing one, on the lower, a shiny, brittle one.

The brittle type of fracture may occur in actual parts despite a high notched-bar figure for the material, tested in the conventional fashion. This is a size effect. When holes are punched in structural steel angles made from unkilled, non-heat-treated steel, a ring around the punched hole is hardened by cold work and its surface is torn and jagged on a microscopic scale. In a bend test

[13] Wiester, H. J.—"Application and Testing of Steels for Use at Low Temperatures", *Stahl & Eisen*, Vol. 63, Jan. 21, 1943, Pages 41-47—through *Bulletin*, Iron and Steel Inst., March, 1943, Page 180a.

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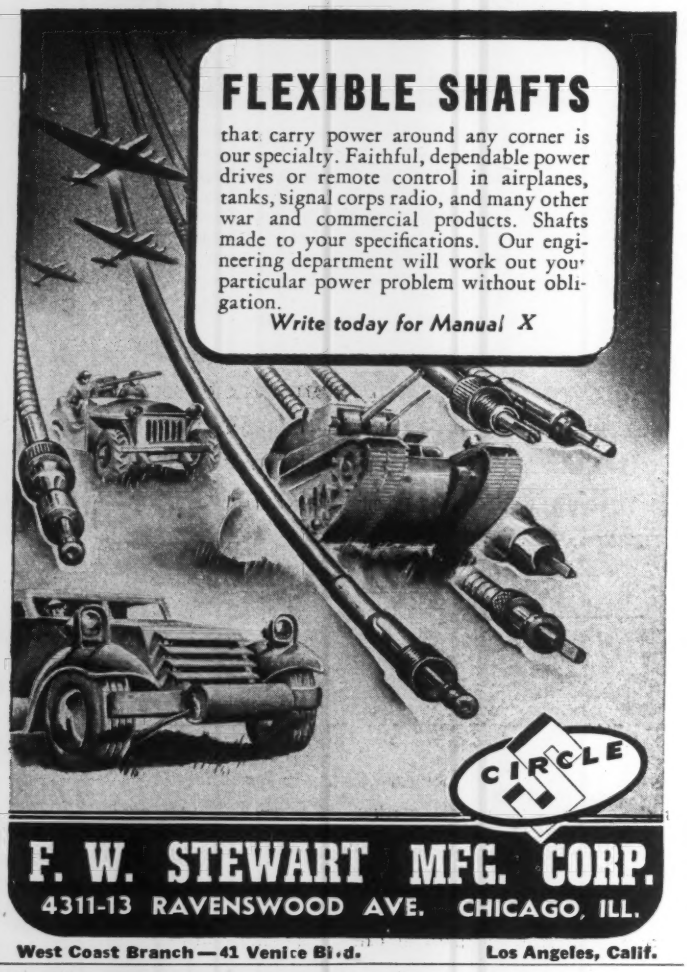
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of the whole angle, fracture may be tough or brittle. In angles of thicknesses of ¾ to 1 inch, such punched holes make ductile steel act brittle at ordinary temperature, whereas subpunching and reaming to remove the torn surface and the cold-worked layer allows it to act as a tough material.

Small punched angles, ⅛ to 5/16-inch thick, however, acted tough, even at —40 degrees Fahr. Punched angles ½-inch thick may behave either tough or brittle. The degree of cold working in punching is, of course, greater in the heavy angles, but the data indicate that the restraint upon deformation, imposed by mere size in the thick angles, is a major factor in governing whether the piece will act brittle or tough.

In any given state of heat treatment, increasing the carbon decreases the impact figure, and if we demand high impact values at very low temperatures, such as that of liquid air, we must keep the carbon low. If we want great strength as well we have to use alloying elements, and those that, like nickel, affect the matrix rather than the carbide, are most effective. As nickel has a large solubility in the matrix, it is the element usually used, and in generous amounts.

Steel Is Sensitive to Finishing

However, a series of tests on low-carbon, high-nickel steels showed them to be sensitive to finishing practice and that the high nickel content was not a cure-all. With all the steels normalized and tempered, a .04 per cent carbon, 2.12 per cent nickel, and a .04 per cent carbon, 3.07 per cent nickel steel both gave Charpy values as low as 8 and 8.5 foot-pounds at 0 degrees Fahr., whereas an .03 per cent carbon, 2.94 per cent nickel steel that had been made with proper deoxidation practice showed a minimum of 18.5 foot-pounds at —100 degrees Fahr.

A properly finished heat-treatable steel that hardens throughout on quenching, properly quenched and well tempered back to, say, easy machinability, is in general well able to withstand even the lowest atmospheric temperatures met in aircraft operation, pretty much irrespective of its chemical composition. In such steels, proper heat treatment may even swamp out the effect of poor finishing practice. It is in non-heat-treated, as-rolled, or normalized steels that the effect of finishing practice becomes notably paramount.

Notched-bar impact figures often reflect some precipitation phenomena in steel that are not shown by hardness or change in tensile strength or ductility. So-called "temper brittleness" in some heats of the more highly alloyed steels, notably the nickel-chromium steels, occurs when the steel is slow-cooled from the tempering temperature—the notched-bar impact figures being decidedly lower than when pieces, small enough to be rapidly cooled at the center by quenching, are quenched from the draw temperature. Long sojourn at around 800 degrees Fahr. may induce a similar phenomenon. Addition of molybdenum is known to be effective in eliminating or greatly reducing the tendency toward temper brittleness. The cause, and the mechanism by which molybdenum serves to counteract it, are not clear. It is clear that the behavior is not due to the ordinary chemical composition, for some heats of steels of compositions often susceptible

Richard M. Bennett examines Army water bag of Saflex-coated fabric. Pennsylvania-born, Ohio-nurtured, and Harvard-trained, he has been combining private practice with teaching at Yale and Vassar, has lately been interested in design of mass-distributed, mass-produced articles from furniture to bath fixtures and fittings.

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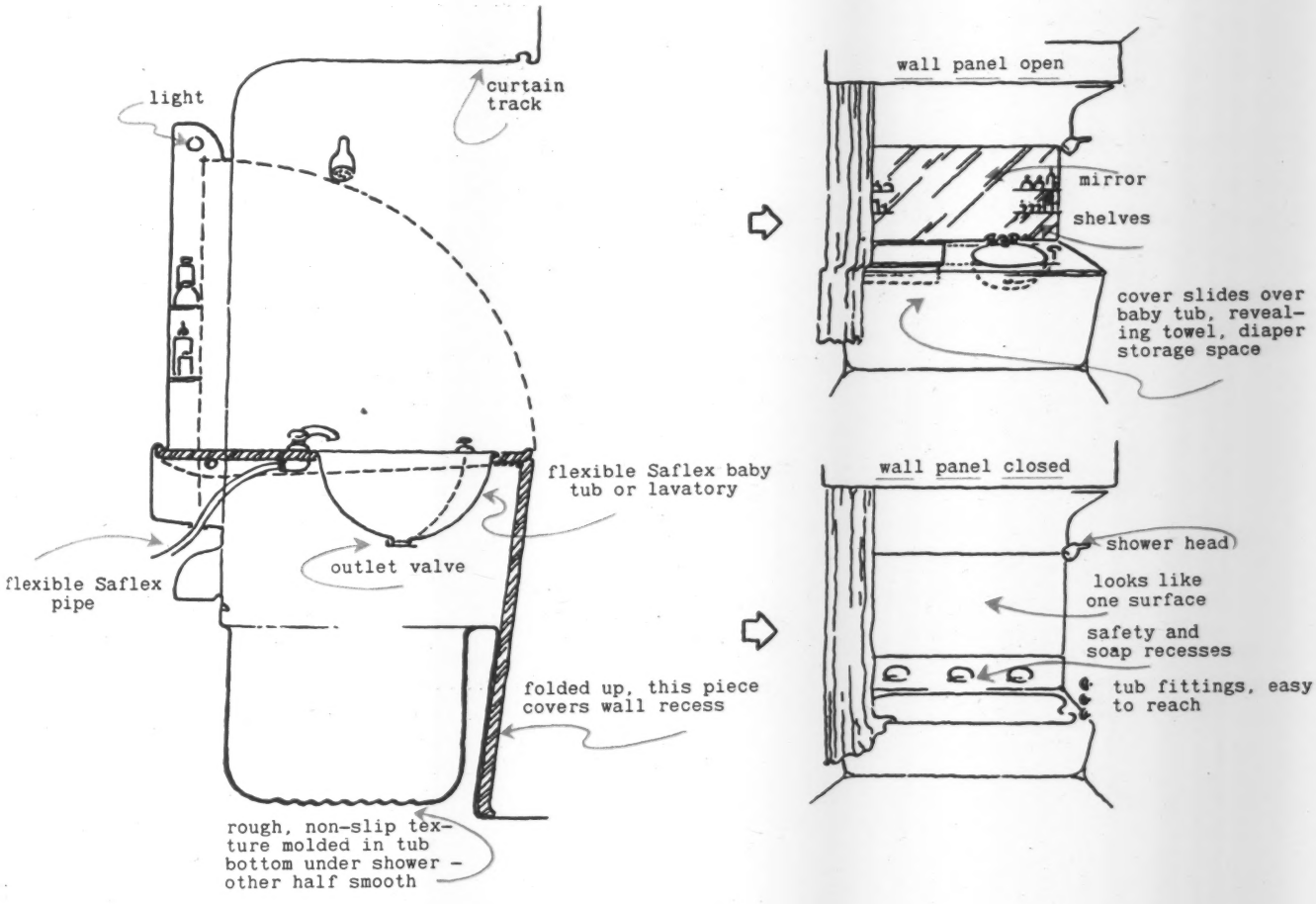
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folded up, this piece covers wall recess
rough, non-slip texture molded in tub bottom under shower — other half smooth
wall panel open
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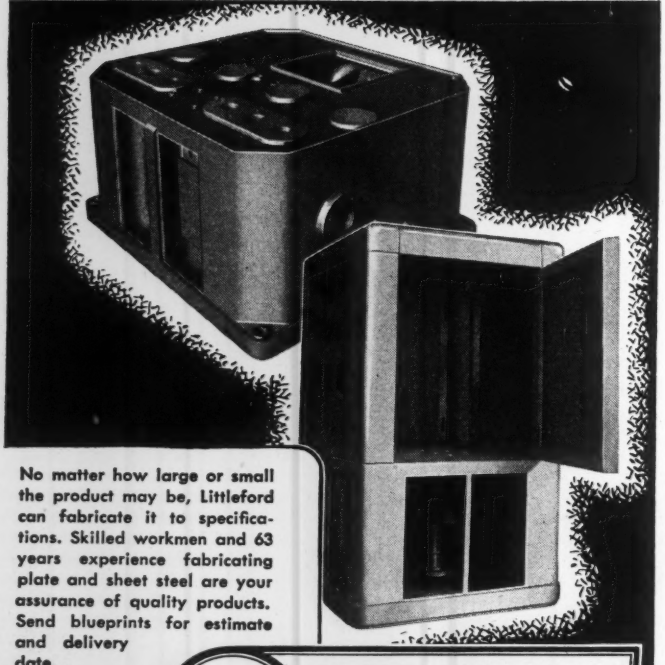

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to it are immune entirely without the addition of molybdenum.

Thus the results of the conventional impact test may steer the thought of the metallurgist into productive channels. For the designer, however, impact test figures have little meaning.

Quality in Steel

It comes out all through the discussion, so far, that composition of ordinary steel and ordinary alloy steels is only a means to an end, not an end in itself, and that there are often greater variations from heat to heat than from composition.

So-called "aircraft quality" steel is often specified for exacting uses. What the designer really means by this vague term is, in effect, that the endurance limit, the notched-endurance limit and the damage behavior of no part shall fall below his expectation. This implies that no location in any ingot shall contain any imperfection of moment.

The general behavior of the heat, as a whole, can be appraised by notched fatigue tests, but a few fatigue specimens do not sample the whole heat well enough to disclose possible local imperfections. These could consist of chemical segregation, unremoved ingot pipe or butt imperfections, shatter cracks, flakes or large nonmetallic inclusions. To prevent the existence of such imperfections in the steel delivered, those parts of the ingot most prone to them are removed.

Inclusions in steel, especially if they are hard and sharp-ended, and if the applied stress in service is at right angles to the sharp ends, are admittedly detrimental to fatigue resistance, if they happen to come at the surface of the finished part. If they are well beneath the surface, they will probably have no effect. Even at the surface they seldom have any more effect than have the irregularities on the surface of a ground part but, on a part polished to give maximum resistance to repeated stress, large inclusions are undesirable.

Effects of Phosphorus and Sulphur

Steel specifications commonly include maximum figures for phosphorus and sulphur, not because the user cares about these elements but because, in hard steels, whether made hard by high carbon in non-heat-treated steels, or by quenching, the combination of high carbon plus too high phosphorus leads to brittleness at room temperature, a type of brittleness revealed either by tensile, ductility or by notched-impact tests.

When the carbon content is low, phosphorus even in double the amount ordinarily permitted does not embrittle and is a useful strengthening element. Nevertheless, the fear of phosphorus caused specifications for low-carbon steels to contain quite illogical low limits for phosphorus, until the advent of the mild alloy steels in which phosphorus was recognized "as a tonic rather than a poison"—as it has been phrased.

Sulphur in excessive amounts does not produce cold shortness but does lead to hot shortness, hence it is avoided from the standpoint of reducing trouble in the mill and foundry. From the user's point of view, sulphur produces inclusions and it is to avoid these inclusions as much as is feasible that sulphur limits are set. However,

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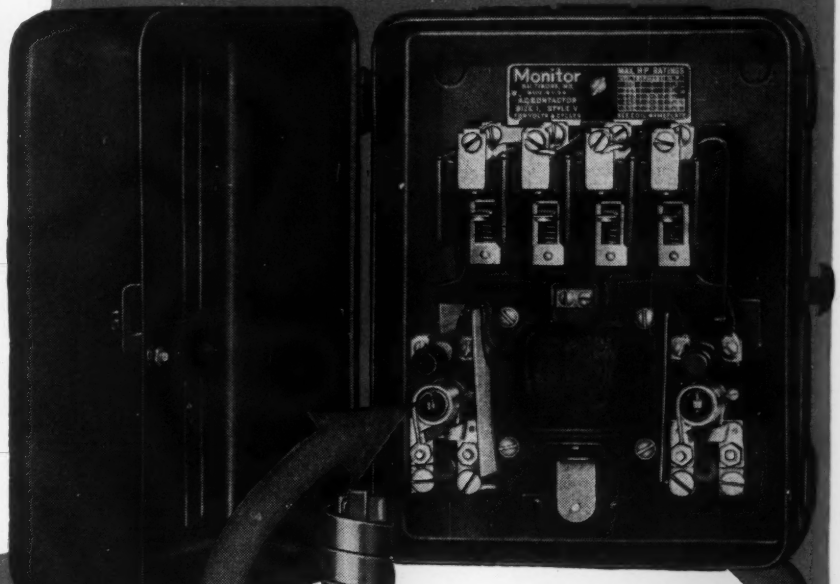

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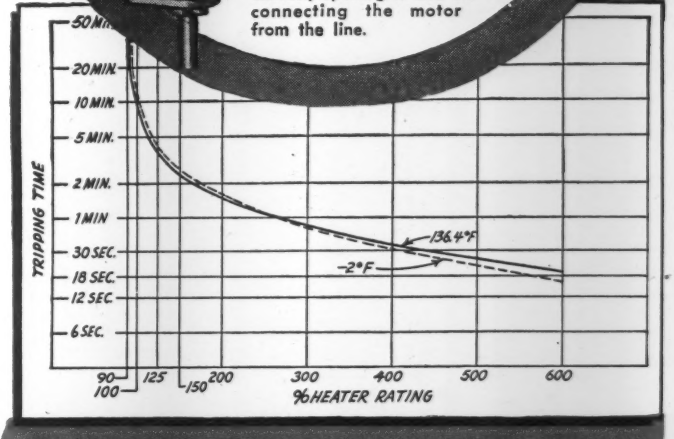

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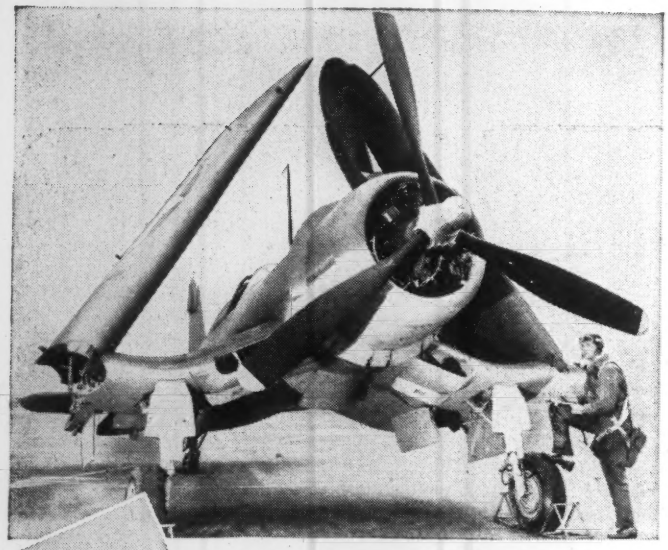

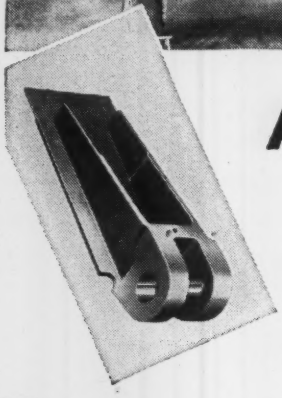

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sulphide inclusions aid machinability.

A vast improvement in gear life has been obtained by a move that, to the average engineer or metallurgist sounds like a depreciation in quality; that is, by raising the sulphur content a bit above that allowed by the usual specifications for steel for heat treatment. The higher sulphur makes the steel machine cleanly without rapidly dulling the tools and making them produce tiny tears on the gear tooth surface. The better surface on the gears makes their life go up by leaps and bounds. The mechanical properties of the steel are doubtless very slightly lowered.

The engineer has little legitimate interest in chemical composition in relation to the properties of steels and alloys for bodily strength; the more rigidly he specifies composition, the more he hampers the metallurgist.

When it is surface behavior such as corrosion, and to some extent wear, rather than bodily strength that is vital, chemical composition may more justly be specified, because chemical reactivity is directly concerned, and chemical reactivity is affected by chemical composition. Even here it is resistance to corrosion or wear that we seek, and it is only because of difficulties in making quick and reliable tests for corrosion and wear that resort is had to the subterfuge of trying to get some approach to an evaluation of these indirectly through chemical composition, rather than by direct tests.

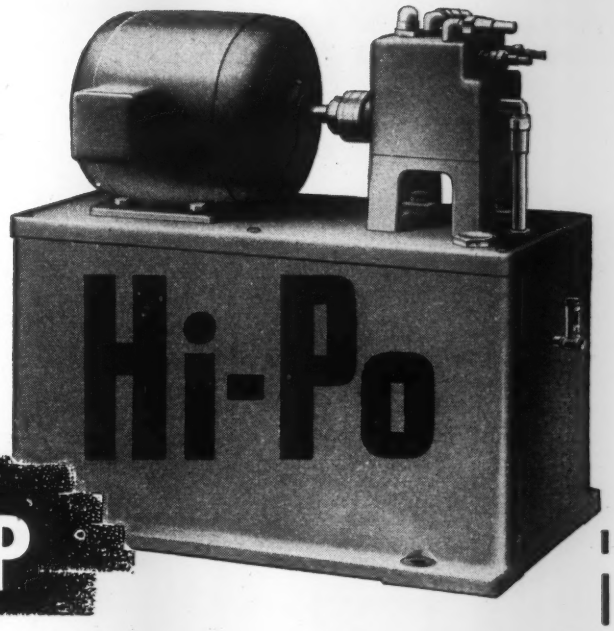
In applying the tests to alloy steels for heat treatment, it is found that hardenability, ductility, endurance, room-temperature notched-bar impact, and low-temperature notched-bar impact tests, all often reveal scatter among individual heats, of an order of magnitude quite as great as among the different steels that have been considered entities on the basis of chemical composition.

When such differences have engineering import, it is not enough to make a series of tests on a prototype steel of a given composition, and rest on the blind faith that all subsequent heats will return the same test results.

Each Heat Should Be Tested

Prototype tests, as made on single heats during the development of the N. E. steels, serve to wipe away fears arising from earlier classification of alloy steels by composition rather than by hardenability. The simulated service tests on replacing S.A.E. by N. E. steels give still further assurance that, with proper control in the steel mill, replacement of one steel by another of equal hardenability is practical, but they do not assure that control will necessarily have been exercised on a given heat to be delivered in the future, whether it be of S.A.E., N. E., or some other composition. For this assurance, the heat needs testing, either by the steel mill or the user.

The tests to be applied depend on what engineering use is to be made of the steel, e.g., if successful service in an engine depends on its fatigue resistance, a notched-fatigue test would give usable information, while data from a low-temperature notched-impact test would have no pertinence. Some more or less standard tests do serve to indicate quality and uniformity of the material as such, irrespective of the service to which the steel is to be put. But the interpretation of the tests, for example what degree of cleanliness needs to be demanded, depends on the true requirements of the service.



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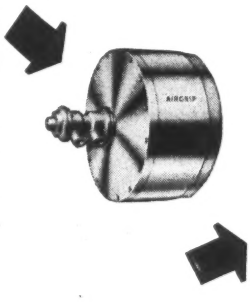

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ADDITION of William Hyndman III to the engineering sales staff of Atlas Tool & Designing Co. and Atlas Metal Stamping Co. of Philadelphia has been announced. Mr. Hyndman has been a representative of the Coplay Cement Mfg. Co., Philadelphia, for the past seven years.

♦

The newly opened Chicago district office of General Radio Corp. at 920 South Michigan avenue, will be under the management of Lucius E. Packard, formerly in charge of the New York office. Mr. Packard will be available as consultant on design, use and procurement of the company's equipment.

♦

According to a recent announcement, French & Hecht, Inc., Davenport, Ia., will become a subsidiary of Kelsey-Hayes Wheel Co., Detroit. No change in personnel of French & Hecht, Inc., will be made.

♦

Fairbanks, Morse & Co., Chicago, has made several changes in its sales personnel. These are: O. O. Lewis has been promoted from branch manager of the company's Atlanta office to assistant general sales manager at the Chicago office. V. O. Harkness, formerly manager of the branch at Dallas, has been made manager of the diesel engine sales division, Chicago. Formerly manager of the oil field division at Dallas, H. J. Renken has been appointed branch house manager of the Dallas branch where he will also continue as manager of the oil field division. Replacing the late Stanley Eaton, J. S. Peterson has been advanced to the position of branch manager at Cincinnati. G. N. Van Epps has been transferred to the company's branch at Atlanta as manager. Prior to this appointment he had been manager of the diesel department, Chicago.

♦

Formerly with General Electric Co., Henry M. Richardson has resigned to enter private practice as a consulting engineer in the plastics field. With headquarters in Pittsfield, Mass., he will be connected with John M. DeBell, plastics consultant, Longmeadow, Mass.

♦

Recent appointment of Stuart H. Betsinger as sales manager has been announced by Kinney Aluminum Co., Los Angeles. Mr. Betsinger was previously sales engineer for over a year. In his new post he will direct the sales of permanent-mold aluminum and magnesium castings, as well as the company's new pressure-type castings.

♦

Howard F. Johnson of the wire and cable department of United States Rubber Co., New York, has been assigned to a new post as manager of branch sales with offices at 1230 Sixth avenue, New York. Previously he was western district sales manager.

♦

Moving to a new plant in Long Island City has increased the production and experimental work facilities of Powder Metallurgy Corp., subsidiary of General Bronze Corp. R. P. Seelig is chief engineer and metallurgist, and R. Hradecky is

Come on Out!

The shadow of the "8" ball can be an unpleasant spot—particularly when it has to do with post-war planning. Many are puzzled about how they will convert to peace. What product shall be manufactured—the previous one or will it be necessary to fare forth into uncharted fields? One thing is certain—and this is where we can help—there is hardly a product necessary for human existence that does not require springs and / or screw machine products. If these are chosen with care and *engineered* into the product, the rest is routine and the "8" ball disappears!

Busy as we are, we'll be glad to plan with you now in establishing a post-war program.

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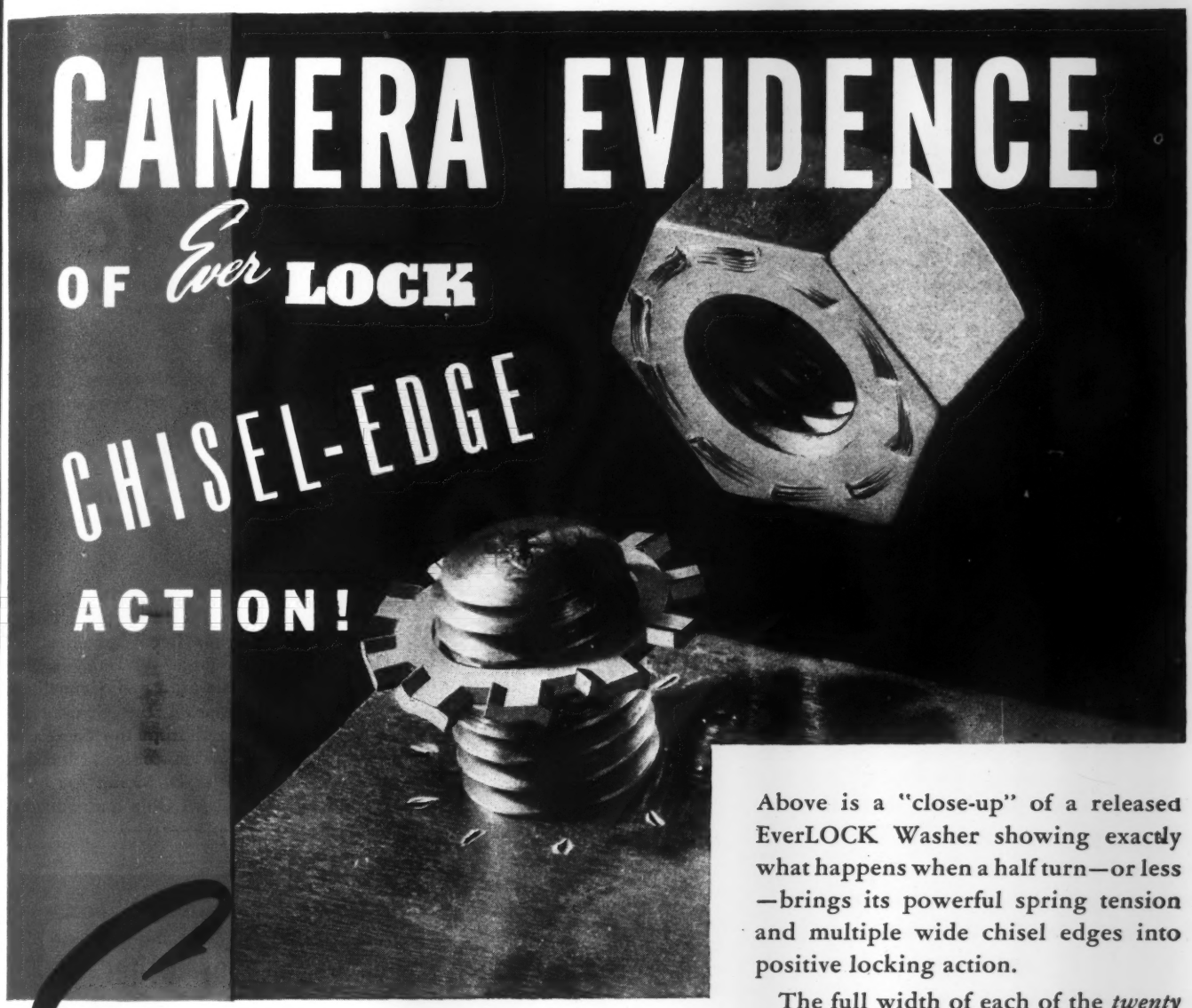

Above is a "close-up" of a released EverLOCK Washer showing exactly what happens when a half turn—or less—brings its powerful spring tension and multiple wide chisel edges into positive locking action.

The full width of each of the *twenty* teeth has left indisputable evidence on both work and nut of having been firmly anchored against vibration, strain, expansion or contraction. This powerful flexing action on many wide chisel edges . . . multiplying the area of resistance . . . is found only in EverLOCK Washers. Combined with this *double indemnity* insurance against loosened bolts, nuts and screws are important savings in assembly time . . . distinctive safeguards against stretching of bolts and screws, and the distortion of threaded parts.

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Ever LOCK WASHERS

THE WASHER THAT HAS THE EDGE

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PROMPT DELIVERY ON MANY SIZES

THOMPSON-BREMER & CO., 1640 W. HUBBARD ST., CHICAGO, ILL.

general manager of the Powder Metallurgy Corp. Mr. Hradecky was formerly connected with the parent company.

♦

The Dow Chemical Co., Midland, Mich., has named Arthur Smith Jr. head of magnesium sales for the southwest area with headquarters at Second and Madison streets, St. Louis. Mr. Smith will cover the territories of Wichita, Kansas City, Tulsa, Dallas, Oklahoma City and Fort Worth.

♦

Appointment of A. G. Fournier as sales and service engineer in California, Arizona and Nevada has been made by Pioneer Pump & Mfg. Co., Detroit. His office is located at 2444 East Twenty-fourth street, Los Angeles 11.

♦

It is with deep regret that MACHINE DESIGN announces the death in action of Lieut. Larry N. Succop. Prior to enlisting in March 1941, Lieut. Succop had traveled throughout the Southwest as sales representative of American Roller Bearing Co., of which his father, Clarence F. Succop, is president.

♦

Recently The Manhattan Rubber Mfg. division of Raybestos-Manhattan, Inc., Passaic, N. J., observed its golden anniversary and appropriately enough received the Army-Navy "E" for excellence in production. The company has operated without loss of a working day since its inception fifty years ago.

♦

Purchase of Asbestos Fibre Spinning Co., North Wales, Pa., has been announced by Greene, Tweed & Co., New York. Plans for enlarging facilities and expanding operations of both companies are being made. The vice president and general manager of Greene, Tweed & Co., O. W. Trumbull, will act in his same capacity with the affiliated company.

♦

Oliver Smalley of Meehanite Metal Corp., New Rochelle, N. Y., was recently elected president of the Meehanite Research institute of America at its second wartime meeting.

♦

Location of American Screw Co. offices has been changed from the General Motors building to Room 502, Stephenson building, Detroit.

♦

Recent appointment of Dr. William C. Theisinger as assistant to the vice president has been announced by Lukens Steel Co., Coatesville, Pa.

♦

Ross Heater & Mfg. Co., Inc. has recently opened a San Francisco branch office at Central Tower, 703 Market street. Richard N. Mathews has been transferred from the Chicago office as manager.

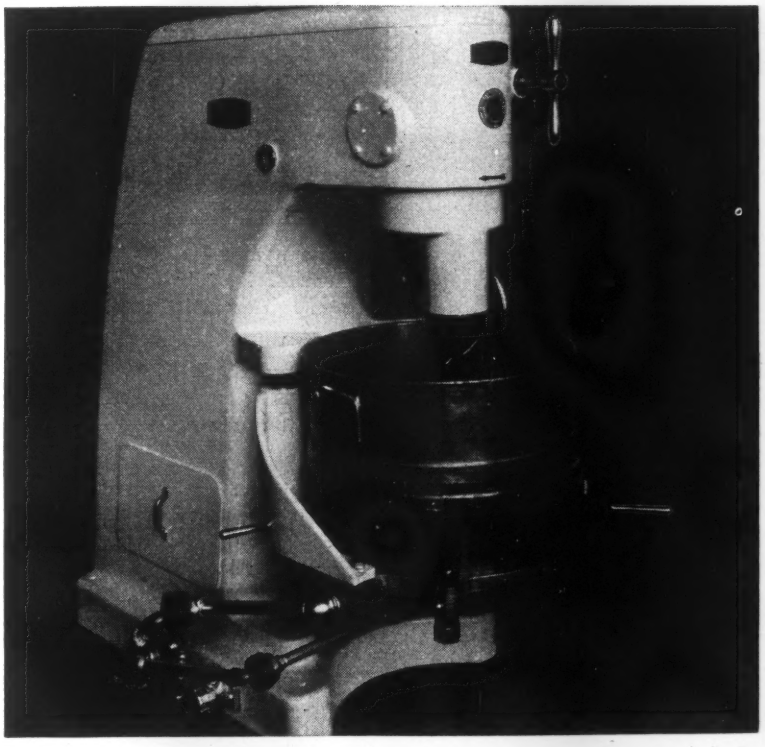
♦

Having resigned as president of Darwin & Milner, Inc., Victor F. J. Tlach has become connected with American Agile Corp., Cleveland.

♦

Several recent additions to the sales organizations have been made by Wheelco Instruments Co., Chicago. The Cochrane Steam Specialty Co., Boston, has been appointed to act with the present representative, George W. Hall, in covering Massachusetts, Rhode Island, Maine, New Hampshire, Vermont and part of Connecticut east of the Connecticut river. C. L. Clark has been transferred from the Cleveland office to be in charge of a Western New York office in Buffalo. With headquarters in Cincinnati, Charles D. Mount has been appointed sales representative for southern Ohio and northern

DESIGN BARCO FLEXIBLE JOINTS IN



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